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National Committee on Wood Utilization

The National Committee on Wood Utilization was established in 1925 by Herbert Hoover its first chairman. The Committee has a membership of 150 leaders in industry, representing producers, distributors, and consumers or users of wood and wood products.

The present volume is sponsored by the following control committee appointed by Mr. Hoover: Wm. F. Chew, Baltimore, Md., builder, representing the National Association of Builders Exchanges; Henry D. Dewell, San Francisco, Calif., civil engineer; F. O. Dufour, Philadelphia, Pa., consulting engineer, United Engineers and Constructors, Inc., representing the American Society of Civil Engineers; N. Max Dunning, Chicago, Ill., architect, representing the American Institute of Architects; W. H. Ham, Bridgeport, Conn., civil engineer, treasurer and general manager, Bridgeport Housing Company; LeRoy E. Kern, New York, N. Y. Technical Secretary, Structural Service Department, American Institute of Architects; T. F. Laist, Yellow Springs, Ohio, Director of Research in Retail Lumber, Antioch College; Ira W. McConnell, Philadelphia, Pa., Senior Vice President, United Engineers and Constructors, Inc.; D. H. Sawyer, Washington, D. C., Secretary, Associated General Contractors of America, and F. E. Schmitt, New York, N. Y., Editor, Engineering News-Record.

The book was prepared by Dudley F. Holtman. It is endorsed by the control committee as being an outstanding, authoritative, and up-to-date work on the efficient use of wood in the building and construction field. Through their cooperative effort and the assistance which they have rendered, the members of the control committee have set a precedent in cooperation and constructive achievement. The National Committee on Wood Utilization takes this opportunity to express appreciation and thanks for their labors.

AXEL H. OXHOLM,
Director.

WOOD CONSTRUCTION

PRINCIPLES—PRACTICE—DETAILS

A PROJECT OF THE
NATIONAL COMMITTEE ON WOOD UTILIZATION

PREPARED UNDER THE DIRECTION OF THE FOLLOWING
CONTROL COMMITTEE

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BY

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Construction Engineer National Committee on Wood Utilization
Member American Society of Civil Engineers and
Western Society of Engineers

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BUSINESS & INDUSTRIAL DEPARTMENT

DEDICATED

to Herbert Hoover to whose initiative the creation of the National Committee on Wood Utilization was due and from whose guidance has come its success.

PREFACE

This handbook is an attempt to supply a rapidly growing need on the part of architects, engineers, and builders for complete and practical information on the use of wood in construction. In part, this need grew out of changes in the wood-using arts and in the lumber industry which supplies these arts. In part, it is due to the fact that construction in wood developed through long ages as a matter of craftsmanship, and many of its essential practices have not been recorded.

Fundamental facts concerning the nature and available forms of wood, and fundamental principles on the use of wood, constitute the most important part of the book. The aim has been to furnish basic information for use in designing and specifying wood construction, and to aid in the efficient selection and application of the material, and in the adoption of efficient and economical forms of design. The handbook should prove equally helpful in the office and on the job.

The first seven chapters include information on the factors affecting the use of wood in construction; lumber grading, grade provisions, and working stresses; the principal woods used in building and construction; the identification of common woods; preservative treatment; the use of paints and stains, and methods of preventing termite damage. The last four chapters contain information on approved methods of using lumber in light building construction and millwork, and in both heavy timber and temporary construction. In an appendix are given compilations showing the standard grades produced in the various species, and tables of the lumber grades used for various construction purposes.

Preparation of the handbook was undertaken to further the movement for elimination of waste, increase of efficiency, and conservation of the country's resources. Waste of our wood resources is due as much to uninformed and inefficient practices in the use of wood as to waste incurred in the forest and in the lumber mill. By showing how a simple unified grading of lumber recently adopted can be applied to give the wood user that kind of material which will serve his particular purpose most economically, and by setting forth the principles of efficient construction, the handbook will diminish waste and will produce a larger return from the lumber dollar.

In preparing this book the National Committee on Wood Utilization drew assistance from a large number of organizations and individuals. Herbert Hoover was its primary inspiration, and the facilities of the

Department of Commerce were at the service of the Committee most liberally. The Forest Products Laboratory cooperated with equal readiness.

S. S. Cook, P. R. Hicks, T. E. Snyder, P. A. Hayward, and H. A. Gardner, have made important contributions to the book. Thanks are also due Irving K. Pond, Cram and Ferguson, John W. Weiss, George W. Niestadt, Clarence A. Jensen, H. E. Cousins, Leonard C. Wason, A. E. Wynn, H. C. Turner, Frederick L. Ackerman, Arthur L. Harmon, and to many other architects and engineers who have furnished blueprints and data, reviewed manuscript, and made many valuable suggestions. Courtesies extended by the United Engineers and Constructors, Inc., of Philadelphia, are also acknowledged.

Grateful acknowledgment is made of the aid rendered by the National Lumber Manufacturers Association. Generous use has been made of its extensive files and facilities, and of invaluable information, heretofore unpublished, resulting from years of research.

To Mary H. Bosworth who prepared the drawings and to Lotta L. Kimball who edited manuscript and read proof, I wish to express my most grateful thanks.

I acknowledge my sincere gratitude to Nelson S. Perkins, C. E. to whom I am especially indebted for untiring and devoted assistance in all phases of the work.

DUDLEY FRANK HOLTMAN.

WASHINGTON, D. C.
May, 1929.

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WOOD CONSTRUCTION

PRINCIPLES—PRACTICE—DETAILS

CHAPTER I

FACTORS AFFECTING THE USE OF WOOD IN CONSTRUCTION

The availability of wood as compared with other structural materials, its low cost, its exceptionally high strength for its weight, and its ease of working both at the mill and in construction have maintained its prestige in the building and construction field for many generations, and late studies, which make it possible to determine by visual inspection the strength of wood within very narrow limits of range, will continue to maintain and to expand its utility and use.

In the past, the characteristic variations of wood were not so important as they are today, because lumber was cheaper and was easily obtained in large sizes and in almost clear grades. The use of clear grades practically eliminated defects and avoided many of the problems caused by variability in lumber. Plentiful supply, moreover, resulted in the use of larger sizes than economical design would indicate. But conditions have changed rapidly in the past 25 years. By experiment we have learned the structural value of the lower grades of lumber. Furthermore, the requirements of modern construction for strict economy in design have been met by the advancing knowledge of wood technology here recorded.

TIMBER RESOURCES OF THE UNITED STATES

The forested area of the world is now about 7,500,000,000 acres or one-fifth of the land area. Russia and the British Empire each contain about one-fifth of the forests of the world, followed by Brazil with around 13 per cent, and next by the United States with 9 per cent. The remaining 38 per cent of the forested area is divided among some 50 countries.

The United States was originally provided with a bountiful supply of the more useful woods. Approximately one-half of the original stand remains. The rest has been lumbered or destroyed either by forest fires or in order to clear the land. Compared to the rest of the world, we are, however, rather well off even yet, provided that we recognize now that

timber is a crop and must be treated as any other crop, *i.e.*, cared for while it is growing and provision made for a new crop after it has been cut.

Regions of Growth and Types of Forests.—The regions of forest growth in the United States are shown in Fig. 1.

In the Northeastern states the stand is made up mainly of spruce, hemlock, second-growth white pine, and the hardwoods—beech, birch, and maple.

The forests of the South and Southeast are of four types: the swamp forests of the Atlantic and Gulf coasts and the river bottoms, which furnish cypress and hardwoods, and the Mississippi Valley, which is a very important hardwood region and center of production; the forests of the coastal plains from Virginia to Texas, which furnish southern yellow pines; the plateau forests, encircling the Appalachian Range and the lower part of the mountain region, which furnish a variety of hardwoods including oak, yellow poplar, chestnut, ash, cherry, and basswood; and the coniferous forests on the higher ridges of the mountains, made up largely of spruce, white pine, and hemlock.

The Lake states in their southern portions contain large hardwood forests made up principally of maple, elm, birch, beech, and basswood, in which conifers are intermingled. Most of the hemlock and pine grow with the hardwoods. Farther north are coniferous forests of hemlock, white pine, cedar, and tamarack, in purer stands.

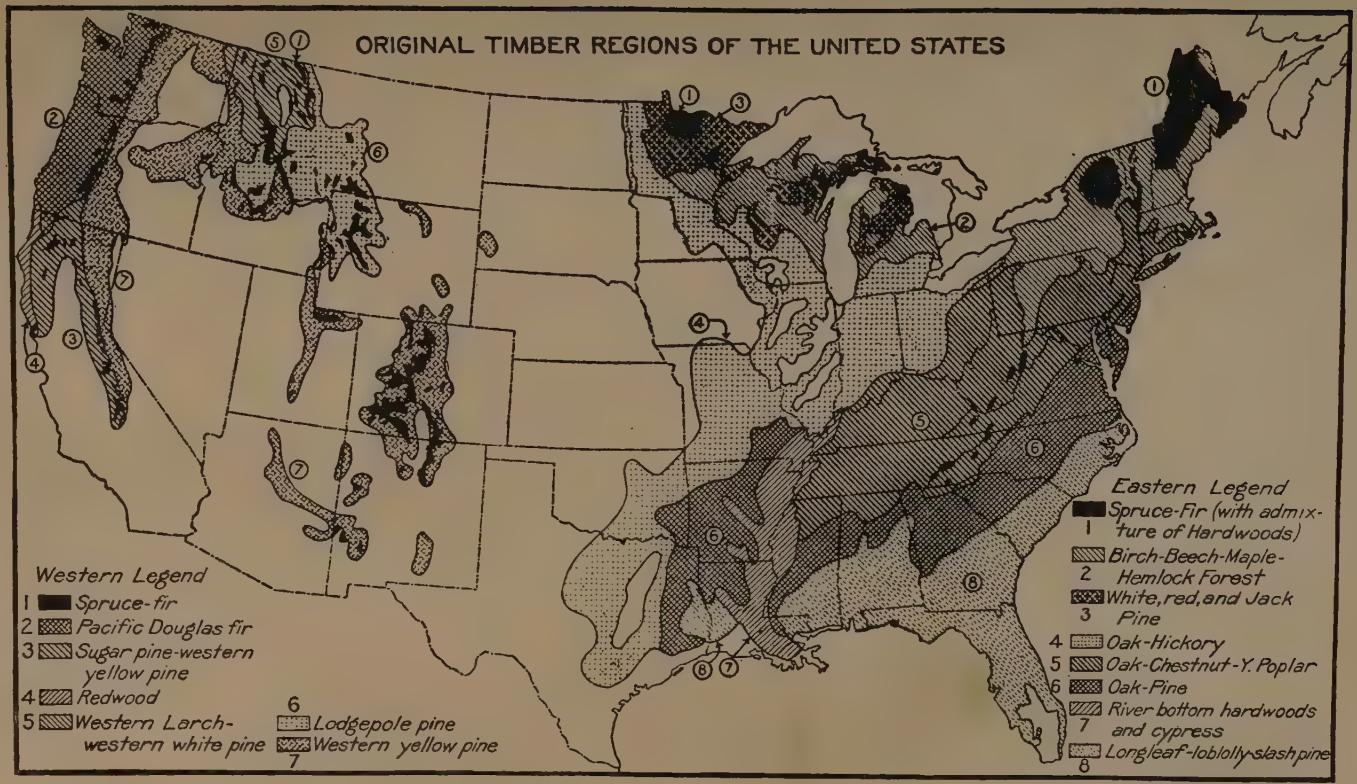
In the forests of the Rocky Mountains and Inland Empire region the principal timber trees are western larch, western yellow pine, western white pine, lodgepole pine, and Douglas fir.

The Pacific Coast forests of Washington and Oregon are made up principally of Douglas fir, West Coast hemlock, Sitka spruce, and western red cedar. Farther south in California, redwood, western yellow pine, sugar pine, and Douglas fir are the principal woods. Hardwoods are comparatively scarce on the Pacific Coast. Certain species of cottonwood, oak, birch, alder, and maple occur in limited quantities.

Estimates of Stand of Timber.—The total stand of timber in the United States on the 470,000,000 acres of forested land is estimated at some 2,200,000,000,000 board feet. Slightly more than one-half is on the Pacific Coast, about one-fourth of the total amount is in the Southeast, and the remainder is distributed throughout the Lake states and the Northeastern states, with a small proportion in the Rocky Mountains.

Figure 2 shows the relative stands of saw timber by states.

Shifting Centers of Production.—The lumber-producing centers in the United States have shifted from region to region as the stand of virgin timber was cut out. Until 1860 the bulk of the lumber produced was cut in the Northeastern states and the Allegheny Mountains. For the next 30 years the stands of white and Norway pine of the Lake states furnished the bulk of the country's lumber. The industry then moved into the

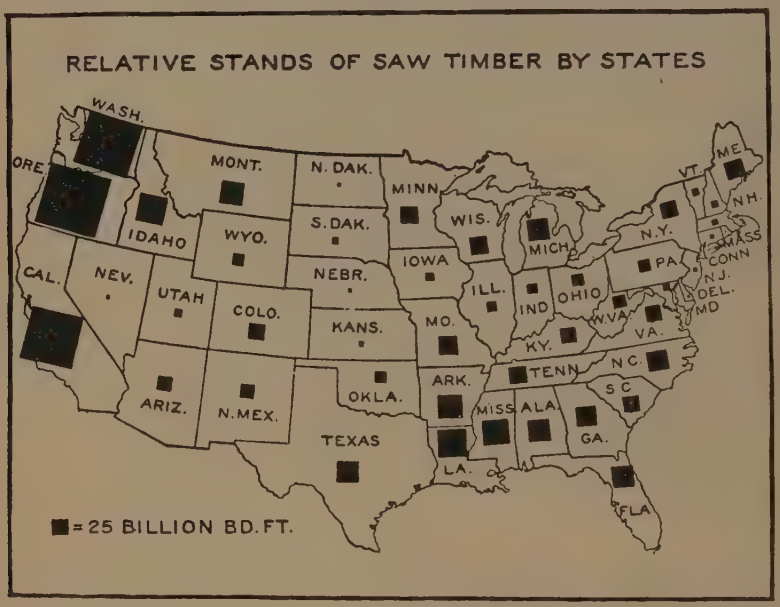


(*Courtesy United States Forest Service.*)

FIG. 1.—The original eastern forests formed 83 per cent and the western 17 per cent of the total. Of our present forest land the East has 75 per cent and the West 25 per cent. But the West now has 61 per cent of the remaining saw timber supply.

southern yellow pine belt on the Atlantic and Gulf seaboard. Meantime, the output of the Pacific Coast region has been steadily climbing, and in time will exceed that of the lumber regions of the East.

Timber Cut Annually in the United States.—Approximately 22,000,000,000 cu. ft. of timber is cut annually from the forests of the United States. There are undoubtedly several billion more cubic feet destroyed by fire and insects, so that 25,000,000,000 cu. ft. is a conservative estimate of the yearly drain. To balance this drain, there is the annual



(*Courtesy United States Forest Service.*)

FIG. 2.

growth which on the Pacific Coast alone, according to the United States Forest Service, may be expected to approximate 14,000,000,000 feet annually as a result of the application of intensive forest-management methods. Sources of supply will continually renew themselves under the careful supervision of cutting, and the scientifically gauged rate of replacement now practiced in both federal and state owned forests. The amount of timber cut annually for various kinds of material is shown in Table 1. The largest single item is fuel wood, followed closely in quantity by lumber. Fuel wood and lumber together make up nearly three-quarters of the material cut annually from our forests.

The average annual lumber production is given in Table 1 as 37,700,000,000 board feet. Lumber production has not been quite as high as this in recent years. The figure for 1926 is 36,935,930 and for 1927, 34,529,450 board feet.

TABLE 1.—TIMBER: WOOD REMOVED ANNUALLY FROM FORESTS OF THE UNITED STATES, WITH APPROXIMATE VALUATION

Material used or destroyed				Equivalent in lumber sawed from same trees			Equivalent in standing timber			
									Total	
Kind	Unit	Quantity	Approximate value or cost,[1] dollars	Hardwoods, M board feet	Softwoods, M board feet	Total, M board feet	Hardwoods, M cubic feet	Softwoods, M cubic feet	M cubic feet	Per cent
Fuel wood	Cords	100,000,000	475,000,000	3,500,000	1,500,000	5,000,000	6,650,000	2,850,000	9,500,000	38.33
Lumber, dimension material, and sawed ties	M board feet	37,700,000	1,138,917,000	9,425,000	28,275,000	37,700,000	2,064,075	6,192,225	8,256,300	33.31
Fencing	Number of posts	900,000,000	225,000,000	165,000	660,000	825,000	360,000	1,440,000	1,800,000	7.26
Ties, hewed	Number	70,000,000	73,500,000	1,680,000	420,000	2,100,000	672,000	168,000	840,000	3.39
Pulp wood	Cords	5,000,000	79,750,000	195,000	2,145,000	2,340,000	48,700	536,300	585,000	2.36
Mine timbers	Cubic feet	293,000,000	56,913,000	439,500	439,500	879,000	197,775	197,775	395,550	1.60
Cooperage:										
Tight staves	M staves	350,000	19,250,000	399,000	133,000	532,000	87,450	29,100	116,550	
Tight heading	M sets	24,000	12,000,000	141,800	36,200	178,000	31,000	8,000	39,000	
Slack staves	M staves	1,200,000	18,000,000	240,400	121,600	362,000	52,800	26,400	79,200	1.27
Slack heading	M sets	90,000	10,800,000	166,500	166,500	333,000	36,490	36,500	72,990	
Hoops	Thousands	120,000	1,800,000	21,500	.....	21,500	7,080	.....	7,080	
Shingles	Thousands	9,000,000	37,710,000	.....	900,000	900,000	.....	198,000	198,000	0.80
Distillation wood	Cords	1,400,000	9,268,000	185,000	.....	185,000	120,000	13,000	133,000	0.54
Veneer logs	M feet, log scale	576,000	25,079,000	587,520	103,680	691,200	90,000	15,980	105,980	0.43
Tanning extract wood	Cords	1,000,000	10,250,000	87,000	.....	87,000	95,000	.....	95,000	0.38
Poles	Number	4,250,000	10,625,000	55,000	200,000	255,000	11,700	43,550	55,250	0.22
Vehicle stock, woodenware, handles, furniture, etc	M board feet	200,000	7,288,000	197,700	2,300	200,000	45,070	730	45,800	0.18
Piling	Number of pieces	1,500,000	6,000,000	40,000	140,000	180,000	7,800	31,200	39,000	0.16
Excelsior wood	Cords	200,000	1,800,000	60,000	15,000	75,000	18,720	4,680	23,400	0.09
Export logs and hewn timbers	M board feet	100,000	3,445,000	50,000	50,000	100,000	9,200	9,200	18,400	0.07
Lath	Thousands	2,000,000	9,620,000							
Total			2,232,015,000	17,635,920	35,307,780	52,943,700	10,604,860	11,800,640	22,405,500	90.39
Destroyed by fire[2]	M cubic feet	1,080,000	10,000,000	500,000	1,750,000	2,250,000	330,000	750,000	1,080,000	4.36
Destroyed by insects, disease, and windfall	M cubic feet	1,300,000	12,000,000	1,000,000	4,000,000	5,000,000	325,000	975,000	1,300,000	5.25
Grand total			2,254,015,000	19,135,920	41,057,780	60,193,700	11,259,860	13,525,640	24,785,500	100.00

Averages from selected records, 1914–1922, except mine timbers, 1905.

[1] Based on values of approximately 1919, milled products at the mill, fuel at point of production, all others at point of consumption except exports (declared valuation).

[2] These figures express mainly that part of the damage done by fire which can be readily stated in dollars, namely, the loss of merchantable timber. Other damages suffered are the loss of young growth and forage, the injury of trees, opening the way to inroads of insects and disease, the deterioration of forest types resulting from the decrease of valuable species which are sensitive to fire, accelerated run-off followed by soil erosion and irregular stream flow, destruction of animals, fish, and birds, and the prevention of recreational use. One of the most menacing features of the present forest situation is the lowered productivity of forest soils, sometimes amounting to absolute sterility, which results from the action of fires.

COMPOSITION AND STRUCTURE OF WOOD

The uses to which wood is put depend upon its properties, and its properties are determined by its chemical composition and its physical structure. The chemical and physical nature of wood is fundamentally different from that of other common structural materials. The chemical composition of all woods is approximately the same. The physical structure, however, varies greatly. It is this variation in structure that is principally responsible for differences in the properties of different woods.

Chemical Composition of Wood.—Wood is made up chiefly of carbon, oxygen, and hydrogen. When perfectly dry about half its weight is carbon, and half oxygen and hydrogen, in almost the same proportion as in water. It contains, also, about 1 part in 100, by weight, of earthy constituents and a similar amount of nitrogen. When wood is burned, all these materials disappear into the air except the earthy constituents. The nitrogen and water taken up by the roots of trees were originally in the air before they reached the ground. It is true, therefore, that when wood is burned those parts of it which came from the air go back into it in the form of gas, while those which came from the soil remain behind in the form of ashes.

Physical Structure of Wood.—Wood, like all other plant material, has a cellular structure. It is made up chiefly of very small tubes or cells of various kinds which have special uses in the life of the tree. Some conduct water from the roots to the crown, some store away digested food, and others merely strengthen the structure of the wood and hold it together.

Most of the cells in wood are very much longer than they are wide and for this reason are called *fibers*. A typical living cell consists of a wall surrounding a cavity which contains a soft jelly-like substance called *protoplasm*, in which the life processes are carried on.

In the wood of living trees, comparatively few cells contain living protoplasm. In most of the cells, the protoplasm disappears as the cells mature and fill up with air or water or with varying proportions of each. Occasionally, other materials such as resins, gums, and mineral matter are deposited in the cell cavities. The cells of wood are all grown together tightly forming a more or less coherent but porous material.

The cellular structure of wood is responsible to a large extent for some of its advantages as a construction material. The cell cavities allow the cell wall to "give"so that nails and screws can readily be driven into lumber, thus affording a comparatively easy means of fastening two pieces together. In most commercial woods, over one-half of the volume is occupied by cell cavities. This makes them relatively soft and easily worked. They, therefore, can be shaped into various forms with simple tools and comparatively little labor.

Because of the cavities in the cells, most woods, when dry, are fairly light for a given volume. This is of advantage in the manufacture of woodwork requiring a certain size but not great weight or strength. The cell cavities act as dead air spaces which retard the transmission of heat and sound, thus making lumber especially adaptable for building purposes, since it tends to keep the heat in during the winter and out during the summer and makes the building comparatively soundproof.

The figure in wood, which for some purposes is an important asset, is due largely to difference in the size and arrangement of its various cells.

On account of its porous nature, wood holds paint so that it will not scale off so readily as when applied to non-porous surfaces such as metal and stone. Preservatives may be forced through the cells and thus increase the durability of lumber. Glue penetrates the fibers and obtains a hold, making it possible to secure a stronger glue joint in wood than in non-porous materials.

Collectively, the different kinds of cells are spoken of as *elements*. A certain size and arrangement of the elements, varying within certain limits, are characteristic of each species or groups of species and help in identifying the different kinds of woods and in judging their qualities.

The wood of cone-bearing or coniferous trees (like the pines and spruces) has but few kinds of cells, while that of the broadleaf trees (such as oaks and maples) is much less simple. But in each case some of the cells have thick walls and small openings, and others have wide openings and very thin walls. In climates, like our own, which have regularly one season of growth and one of rest, the cells of the layers of new wood formed each year are arranged in a definite way. When growth begins in the spring, and the fresh twigs and leaves come out, there is a great demand for water in the crown to supply these moist green new parts of the tree. Water rises in most trees through the newer layers of the wood and especially through the last ring. Consequently, at first the tree makes thin-walled cells with wide openings, through which water can rise rapidly to the ends of the branches. Later on, when the demand for water is not so great, and there is plenty of digested food to supply material, the cells formed are narrow and thick walled. Thus, the summerwood in each year's growth is heavier, stronger, and darker in color than the springwood. In such species as maples and gum, which have no well-defined springwood, this does not hold.

It is correct to speak of each year's growth in trees in the temperate zone as an "annual ring," for as long as the tree is growing healthily it usually forms a ring each year. Occasionally, a tree does not produce a layer of wood over its entire trunk for a year or several years, and so no annual rings are formed in certain sections of the trunk. On the other hand, two rings may appear in one year, but they are generally so much thinner and less sharply differentiated from each other than the rings on

each side that it is not hard to detect them. Very often, both do not extend entirely around the tree, as a true ring always does in a normally growing tree. Whenever the growth of the tree is interrupted and begins again during the same season, such a false ring is formed. This happens when the foliage is destroyed by caterpillars and grows again in the same season or when a very severe drought in early summer stops growth for a time, or it may also happen after late spring frosts.

HARDWOODS AND SOFTWOODS

No definite degree of hardness divides the "hardwoods" from the "softwoods." In fact, the only absolute distinction which can be made between the two classes of wood has nothing to do with their hardness or softness.

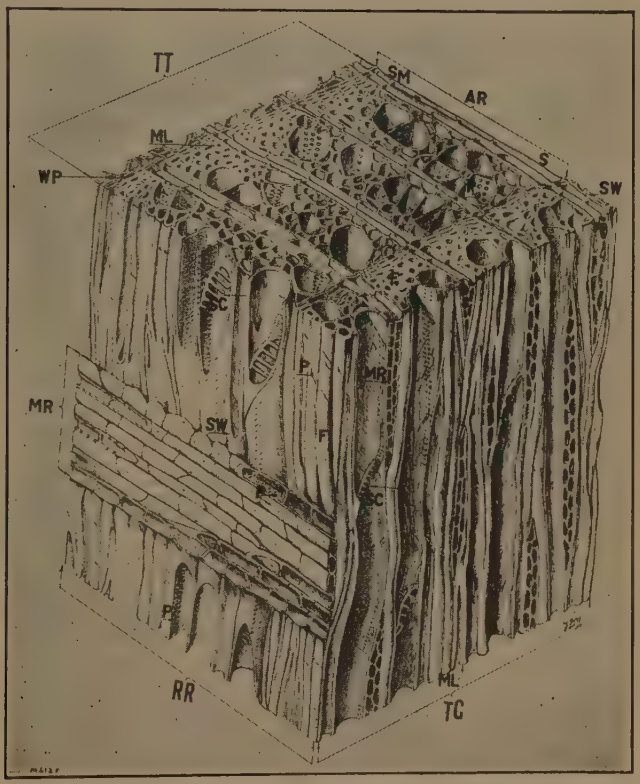
The principal botanical distinction between these groups is that the seeds of the hardwoods are enclosed (angiosperms) and that the undeveloped seeds of the softwoods are exposed (gymnosperms). This distinction is in itself of no commercial importance. But there are numerous general differences which make it necessary for wood users constantly to refer to these two groups by some name or other. Differences in structure, appearance, properties, size, quality, manufacturing methods, and regions of growth keep the woods of the two groups separated, from the logging operation down through the manufacturing process to ultimate use.

The terms *hardwoods* and *softwoods* are the most generally accepted popular names for the two classes of trees, although they are perhaps the most misleading in meaning. It is true that many so-called hardwoods, such as oak, hickory, sugar maple, and black locust, are notably hard and that many so-called softwoods, such as most pines and spruces, are rather soft. But there are a number of outstanding exceptions. Basswood, poplar, aspen, and cottonwood, which are all classified as hardwoods, are, in reality, among the softest of native woods. Longleaf pine, on the other hand, is about as hard as the average hardwood, although it is classified as a softwood. Yew, another so-called softwood, is about three times as hard as basswood and considerably harder than most oaks.

Another common name for the softwoods is "conifers." This is more accurate than softwoods, as all native softwoods except those of the yew family are cone bearing.

Softwoods are sometimes spoken of as "the evergreens," and hardwoods as "the deciduous trees," from the fact that most trees in the former group keep their foliage the year round and most of those in the latter group lose their leaves during the fall or winter months. The exceptions among the softwoods are bald cypress and tamarack, which have no leaves in winter. With hardwoods it is more or less a matter of climate. Many tropical hardwoods are green the year round.

The most accurate popular description of the two groups is "trees with broad leaves" for the hardwoods, and "trees with needles or with scalelike leaves" for the softwoods. These are the definitions generally given by dictionaries for hardwoods and softwoods or hardwoods and conifers. They divide the native woods almost exactly in accordance with botanical grouping. The few softwoods that have broad leaves, such as the ginkgo, are not native to this country.

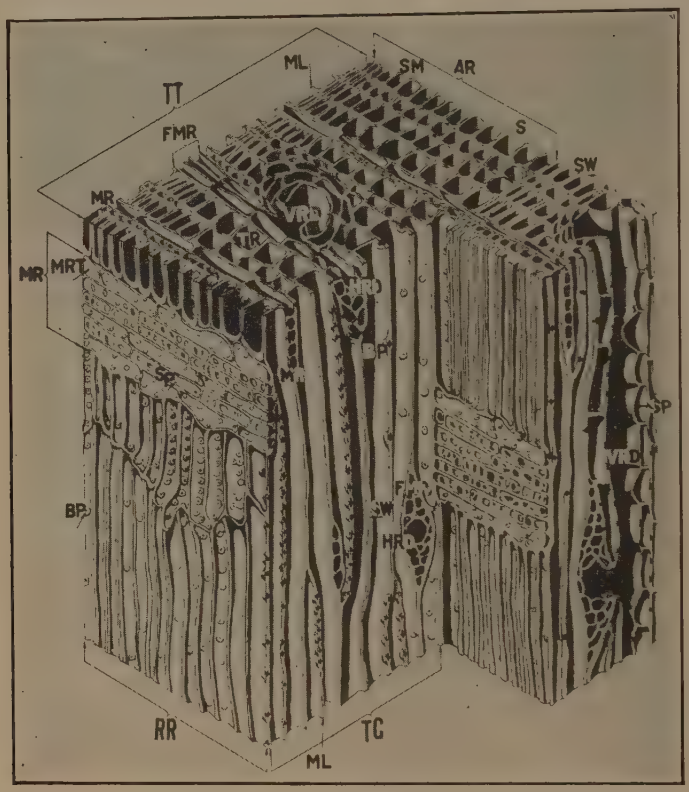


(*Courtesy Forest Products Laboratory.*)

FIG. 3.—Drawing of a small cube of hardwood highly magnified: *TT*, transverse surface; *RR*, radial surface; *TG*, tangential surface; *AR*, annual ring; *S*, springwood; *SM*, summerwood; *MR*, medullary ray; *F*, wood fibers; *V*, vessels, or pores.

The difference in cellular structure between hardwoods and softwoods is a reliable means of distinguishing between the two groups—the hardwoods being called the porous and the softwoods the non-porous woods. The term "porous" refers to the presence of certain comparatively large open-end cells or pores in the wood, in addition to the small closed-end cells, or fibers. These large specialized cells are found in practically all hardwoods, their function being to conduct sap from the roots to the leaves. The softwoods have developed no pores for this purpose but use their fibers to elevate sap.

The Structure of Hardwood.—The drawing (Fig. 3) of the cell structure of a minute block of hardwood brings several planes into sharp focus at the same time. The block shown here was less than ¼ in. high. The top surface of the block corresponds to the top surface of a stump or to the end surface of a log. The larger openings on this surface are sap-con-



(*Courtesy Forest Products Laboratory.*)

FIG. 4.—Drawing of a small cube of softwood highly magnified: *TT*, transverse surface, *RR*, radial surface; *TG*, tangential surface; *AR*, annual ring; *S*, springwood; *SM*, summerwood; *MR*, medullary ray; *R*, tracheid, or fiber; *HRD*, horizontal resin duct. The large hole near the center of the transverse surface and the passage along the right edge are vertical resin ducts.

duction vessels, or pores, built up of short cylindrical cells relatively large in diameter, joined to one another at the ends. The presence of these pores, which in many species are visible without the aid of a lens, helps to distinguish a hardwood from a softwood, the latter being made up of smaller cells of fairly uniform size. The pores are usually larger and thinner walled in the springwood or wood formed early in the growing season than they are in the summerwood which has more of the smaller wood fibers.

The medullary ray consists of many chains of short cells which radiate toward the bark of the tree and serve to store food material and to distribute it horizontally.

The radial surface is called *quarter sawed* in the hardwoods. The attractive figure of large lustrous flakes, made by medullary rays entering and leaving the plane of the saw, causes some quarter-sawed hardwoods such as oak and sycamore to be highly esteemed.

The Structure of Softwood.—The drawing (Fig. 4) of the cell structure of a minute block of softwood (white pine) shows a magnified view of a cube less than ¼ in. on a side. The top of the block represents a plane parallel to the top surface of a stump or the end surface of a log. The rectangular units which make up this surface are sections through vertical cells, mostly fibers, the walls of which form the bulk of the wood substance. Between the various cell units is a cementing substance. Springwood cells, distinguished by their greater size, and summerwood cells are formed during the early part and the latter part of a year's growing period, respectively. The growth of the springwood is the more rapid.

The function of the medullary rays is to store and to distribute horizontally the food material of the tree. These rays are found on end surfaces as fine white lines radiating toward the bark. The large hole in the center of the top surface is a vertical resin duct.

The left side surface represents a vertical plane along the radius of the trunk. This surface, commonly called *edge grain* or *vertical grain* in softwoods and *quarter sawed* in hardwoods, is not so distinctly marked in the softwoods as in some hardwoods.

HEARTWOOD AND SAPWOOD

Annual layers once formed do not change in size or place during the healthy life of the tree, except that they are covered in time by other outer layers. A nail driven into a tree 6 ft. from the ground will still be at the same height after it is buried in 20, 50, or 100 layers of annual growth. In trees like the oaks and pines, however, the wood that has been in the tree for some years becomes darker in color. In some species the openings of certain pores become choked so that the sap can no longer run through them. From living sapwood, in which growth is going on, it becomes heartwood, which is matured because it has nothing to do with growth. It is simply a strong framework which helps to support the living parts of the tree. This is why hollow trees may flourish and bear fruit. The chief reason why sapwood rots more readily than heartwood is that it is not infiltrated with toxic material. Since water from the roots rises only in the sapwood it is easy to kill trees by girdling them, provided all the sapwood is cut through.

A great many theories have been proposed to account for the rise of water into the tops of tall trees, some of which, as in California, are over 300 ft. from the ground; but none of these theories is quite satisfactory.

More than 600,000 tests have been made at the Forest Products Laboratory, Madison, Wisconsin, on the various species of wood grown in the United States, and no effect upon the mechanical properties of wood due to its change from sapwood into heartwood has ever been noticed. Any difference in strength between heartwood and sapwood can usually be traced to differences in the growth and density of the wood.

There are, however, differences between heartwood and sapwood which have an important bearing on their use for various purposes. Since the sapwood of most American species is considerably less resistant to decay than the heartwood, the sapwood is likely to have a much shorter life, where wood without preservative treatment is used in situations that favor decay. In these particular cases, therefore, strength requirements may have an indirect bearing on the choice between heartwood and sapwood, inasmuch as wood infected with decay is likely to have its strength properties, particularly its shock resistance, greatly reduced.

PHYSICAL AND MECHANICAL PROPERTIES

There are many properties of wood that are important in one or another of the uses to which timber is put. In very few instances will data of strength alone be sufficient to determine the value of a species for a given use.

There are few, if any, cases in which two species of wood have all the various properties to the same degree or in the same relative proportions. This fact accounts for the special uses of the different species and for the difficulty in finding substitutes for certain species in particular uses. Confusion arises from comparing species for a certain use upon the basis of properties or strength values which are not of first importance in that use. In the preparation of specifications and grading rules it is essential to know the relation between physical and mechanical properties of wood.

Physical properties are those that have to do with the structure of wood, such as density.

Mechanical properties are those that enable the wood to resist deformations, loads, shocks, or forces. Thus, the ability to resist shearing forces is a mechanical property of timber. The mechanical properties important in construction are: in beams, modulus of rupture, modulus of elasticity, and shear; in columns, modulus of elasticity, and crushing strength in compression parallel to the grain. In flooring, the desirable properties are hardness and minimum shrinkage.

The factors affecting the properties of wood are so numerous that it is impossible to get dependable test results by testing only large-sized

timbers. The data on small clear specimens accumulated by the Forest Products Laboratory give reliable information on the relation between strength and density, moisture, locality of growth, and soil conditions. By testing small clear specimens the influence of defects is eliminated. An important feature of timber testing is the elimination of a maximum number of variable factors. A large number of tests has also been made by the Forest Service on full-sized timbers to determine the influence on strength of defects such as knots, shakes, and slope of grain. These tests serve as a guide to the use of data from tests on small specimens, in establishing working stresses and grading rules for structural timbers.

HISTORY OF TIMBER TESTING

Extensive series of tests dating back as far as the middle of the last century have been conducted to determine the effect of defects and other inherent characteristics which influence the behavior of wood in the uses to which it is put in the building and construction field. These investigations were begun by French scientists, but because of the limited scale upon which the work was done and the crude methods employed the results were necessarily contradictory and unsatisfactory. Most of the modern work in timber testing is based upon investigations made in Germany between 1860 and 1880.

It is believed that an acquaintance with the history of timber testing in this country will give color and add interest to the facts presented in this chapter, and, therefore, results of the efforts that have been made during the past 50 years to throw light on the properties of wood from the standpoint of the architect, engineer, contractor, and builder will be briefly outlined.

The earliest tests on the strength of wood in this country were made at the Watertown Arsenal, Watertown, Massachusetts, between the years 1881 and 1884, and the data were published in 1884 in connection with the tenth census report. The lumber for these tests was selected by Charles F. Sargent and was air dried. But the tests were too few in number to give more than a rough indication of the properties of the wood from a given species. While the material was in an air-dried condition, moreover, no moisture determinations were made and the test specimens were selected from the butt, which subsequent tests have shown to be the most variable portion of the tree.

The next important series of timber tests was conducted at St. Louis under the supervision of Prof. J. B. Johnson. These tests were begun about the year 1890 and offered real possibilities. But the work was discontinued and the record of the tests was lost. The published bulletins giving the outline of this work, however, have been of great importance in formulating the timber-testing program at the Forest Products

Laboratory, where work has been carried on continuously since its inception.

The early work done by the United States Forest Service was divided among a number of schools, timber-testing stations having been located at Yale University, Purdue University, University of California, University of Colorado, University of Washington, and University of Idaho. Other tests were carried on in this early period at Philadelphia, Washington, District of Columbia, and Charleston, South Carolina. The Forest Products Laboratory was established at Madison, Wisconsin, in 1910, since which time all timber-testing work of the Forest Service has become centralized there.

Aside from this early work done under the auspices of the Forest Service, various schools have made series of tests and some work has been done by commercial organizations. The Santa Fé Railroad, for example, at its laboratory in Topeka, Kansas, is believed to have done more in this field than any other organization outside of the Forest Service.

TEST INFORMATION AND DATA

It is easy to misinterpret test information and data. A clear understanding of the significance of test figures, therefore, is essential. The chief distinction, for example, between the data given in *United States Department of Agriculture Bulletin* 556 of the Forest Service, entitled "Mechanical Properties of Woods Grown in the United States," and working stresses for structural sizes, as given in *Circular* 295 from the same source, is that the data in *Bulletin* 556 are elastic limit and ultimate strength values on small sizes, free from defects, while working stresses are for large sizes containing defects, and their determination is subject to other factors, such as minimum strengths as well as averages, effect of length of time under load, susceptibility to conditions of exposure, and whether or not a species runs characteristically high or low in the grade. All of these factors and characteristics should be taken into account in determining working stresses from tests on small, clear pieces.

These factors and characteristics sometimes dictate a considerable variation in the relative status of species as to whether small, clear sizes or structural sizes are the basis for comparison. One species may run characteristically lower in strength than another in small, clear sizes while running consistently higher in structural sizes on material of equivalent character.

The strength values shown in the tables in *Bulletin* 556 are for clear wood in sizes such as are used for factory or industrial purposes and do not apply to structural material containing defects. The clear specimens tested and compared in this bulletin were $2'' \times 2''$ in cross-section. Sizes larger than $2'' \times 4''$ usually cannot be obtained in strictly clear material.

Factors of safety by which results on small, clear pieces may be divided to get working stresses are given in *Bulletin* 556 but are qualified as being applicable only to "carefully selected structural timbers, with all exceptionally light weight pieces excluded." This bulletin was published in 1917, before grades for structural timbers had been developed and specific working stresses recommended. It is not now intended that any species conclusions shall be drawn from the data in *Bulletin* 556, except as to clear material in small sizes.

It would take an extensive series of tests on large sizes to get average results which could be presented as averages of species, or even as averages of grades, and many factors in addition to absolute test results, must be considered in developing working stresses. Fortunately, the effect of equivalent defects is practically proportional, regardless of species, so that tests on small, clear pieces, plus knowledge of the prevalence and effect of defects within a species, and the behavior of species under various conditions, result in the determination of safe working stresses within narrow margins of variation.

DENSITY

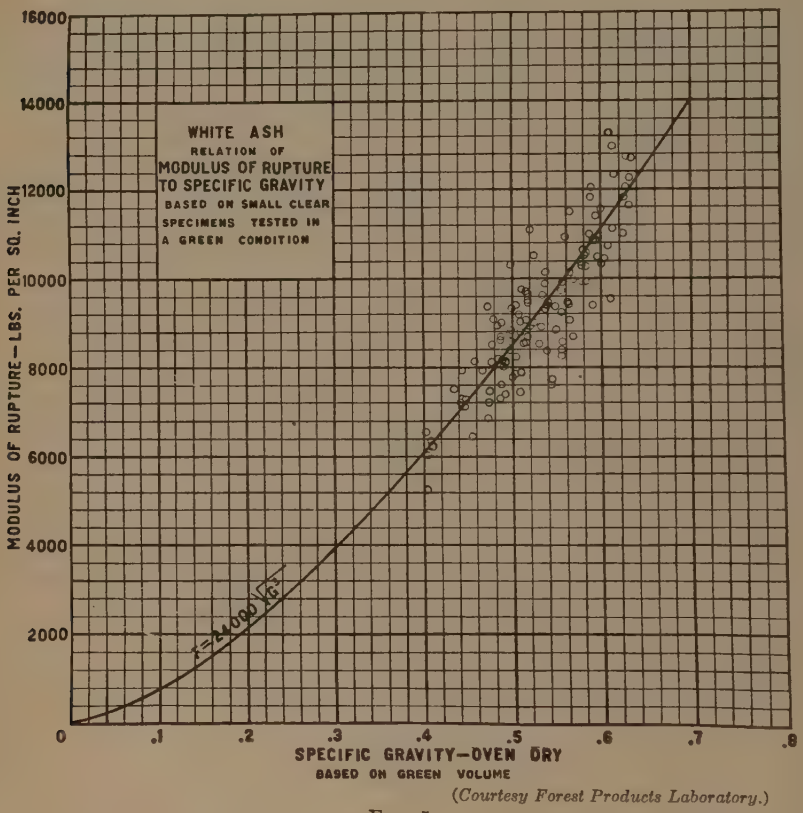
One of the principal factors causing differences in strength is variable density. Everyone has observed that substances of a similar size may differ in weight. Likewise, some species of wood average heavier than others, and, again, pieces of the same size and species differ greatly in weight. These differences may be spoken of as variations in "density." By the density of a body, then, is meant the mass or quantity of matter contained in a unit volume. As might be expected, the greater the density of a given stick, or the more wood it has per unit volume, the stronger the stick will be.

The density of a body is usually expressed in terms of specific gravity, which is the ratio of its mass per unit volume to that of water. For the purpose of this discussion, density and specific gravity may be considered the same. By definition, the density of water is 1.0. The density of platinum is 21.4, which means that a piece of platinum is 21.4 times as heavy as an equal volume of water. When the specific gravity of a body is more than 1 it will sink in water, and if less than 1 it will float.

It should be remembered that the small fibers or cells of which wood is composed are hollow. Each fiber may be likened to a small glass bottle. When a tightly corked, empty bottle is placed in water it will float. When the cork is removed or the bottle broken the glass will sink. Just so it is with a wood fiber, if we could imagine handling in the same way this slender tube only about one-seventh of an inch in length and two-thousandths of an inch in diameter, in softwood. The sealed fiber, when dry, would float. If cut in two so that the encased air could easily be replaced by water, the fiber would sink; for, like glass, wood substance is

heavier than water. The specific gravity of wood substance has been found to be about 1.5.

So far, we have considered wood from the standpoint of the individual fiber, or cell. Any piece of wood contains many such fibers or cells. From a practical standpoint it is the density of the piece as a whole, including its cell spaces, pores, and vessels, or what is called "bulk" density, on which its properties and uses must be determined. From the fact



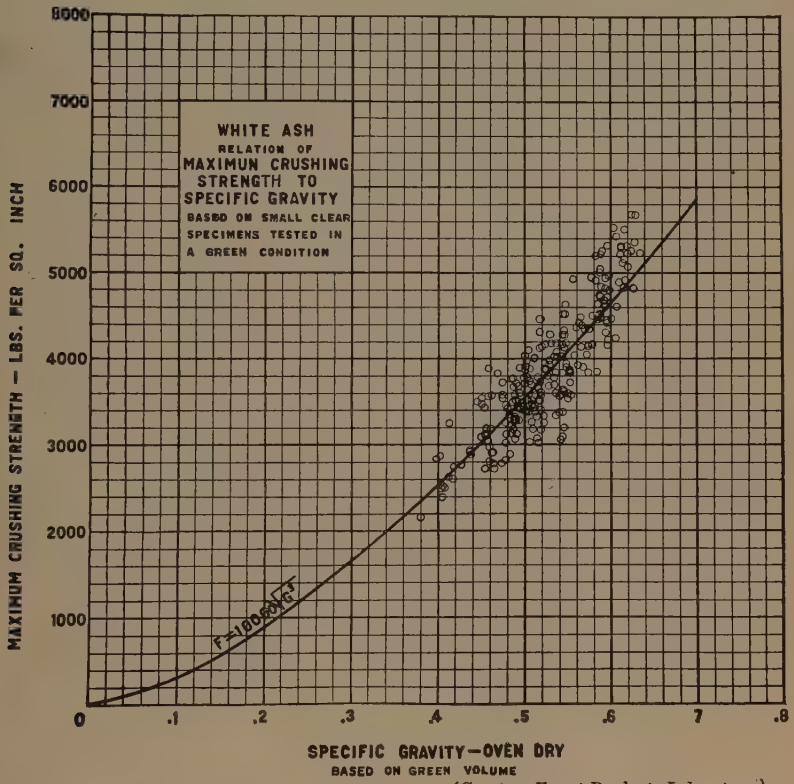
(*Courtesy Forest Products Laboratory.*)

Fig. 5.

that the density of wood substance, regardless of species, is about 1.5 times that of water, it is evident that differences in bulk density of wood are due to differences in the amount of wood substance present, except when moisture and infiltrated material, like resin, are found.

If some pieces of wood contain more wood substance than others, it must be because some have thick-walled cells and small cell cavities. This is found on microscopical examination to be the case. Since the thick-walled cells are stronger and stiffer than those with thinner walls, it follows that the denser pieces should have the greater strength.

The differences in the strength of the various species are usually taken care of by specifying separate working stresses for individual species. The enormous amount of testing necessary to determine the average strength of the clear wood of the various native species has been largely completed, and the results for 126 species have been published. Data on approximately 40 additional species are available but not yet published. There is, therefore, ample information covering the average strength of the clear wood of species commonly used in building.

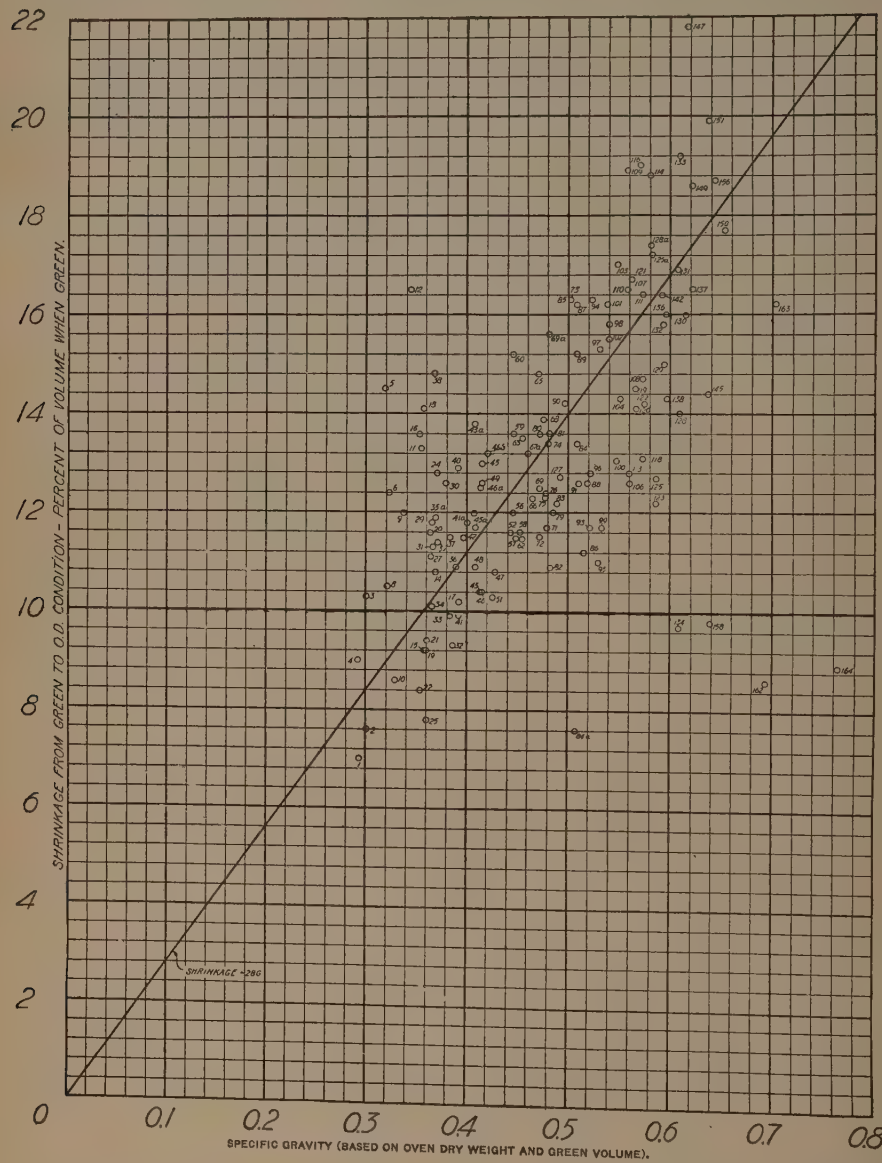


(*Courtesy Forest Products Laboratory.*)

FIG. 6

Variations within a species, however, are such that it is not uncommon to find one piece twice as strong as another, although both are sound, clear, and straight grained, and at the same moisture content. Such a variation is usually associated with a difference in density and may be accounted for either by a difference in the position of the pieces in the tree, by tree characteristics, by conditions under which the tree grew, or by a combination of these factors. Plotted curves based upon the results of tests indicate that as the specific gravity or dry weight or density increases the strength also increases in a fairly uniform manner (see Figs. 5 and 6).

In all species, strength generally increases with an increase in weight, according to the product of a constant times a power of the weight. For



(*Courtesy Forest Products Laboratory.*)

FIG. 7.—Relation of shrinkage from green to oven dry conditions to specific gravity.

Sitka spruce, for example, the following equation has been derived which enables anyone knowing the weight of a piece of spruce to estimate its strength with remarkable accuracy:

$F = 25{,}000G^{1.5}$, where F = fiber stress and G = specific gravity

The relation of density to the properties of wood may be considered from the standpoint of

1. Differences between species.
2. Differences between pieces of the same species.

Considering differences between species, two extremes are found in mastic, a dense Florida wood, and balsa, a very light Central American species. Endwise compression tests on green material gave the following results:

	1	2	3
	Density (based on oven-dry volume and weight)	Crushing strength parallel to grain, pounds per square inch	Specific strength (column 2 divided by column 1)
Mastic	1.034	5,880	5,687
Balsa	0.113	644	5,699

From the above it may be observed that mastic averaged about nine times as high in crushing strength along the grain. Weight for weight, the endwise crushing strength of these diverse species is the same.

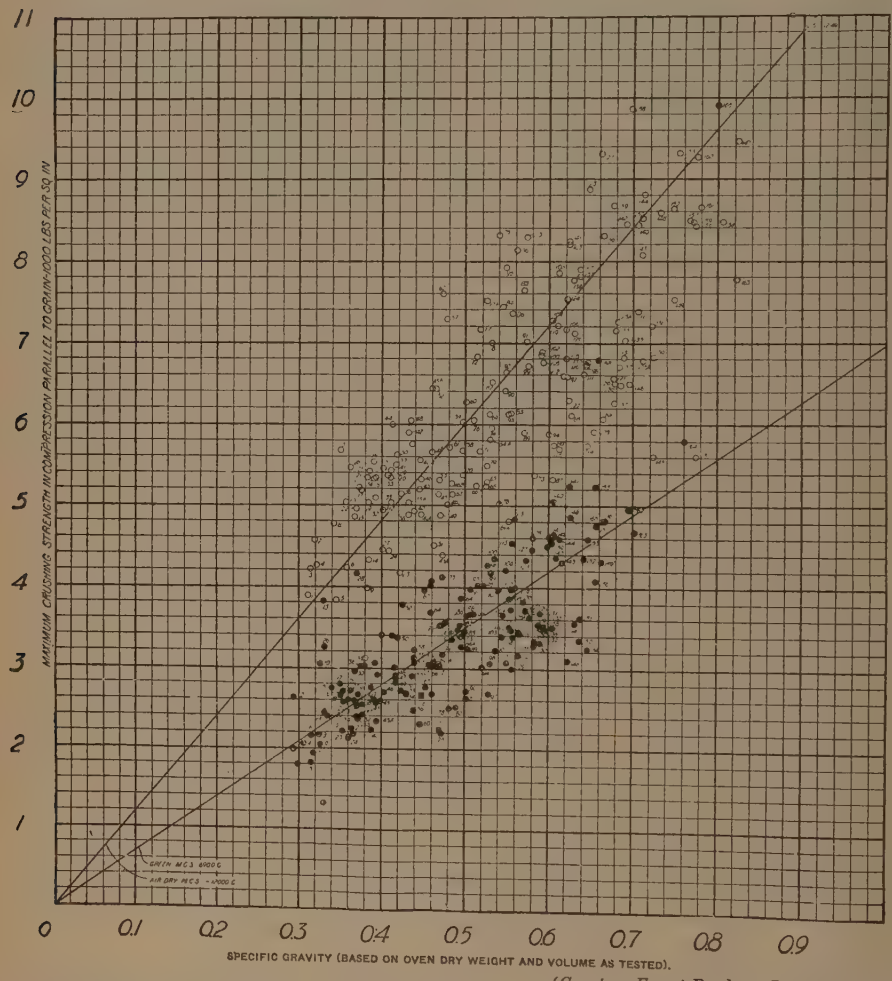
Some properties increase directly with increase in density, while others increase more rapidly than the density increases. Crushing strength parallel to grain and shrinkage are examples of properties which vary directly as the density. A species twice as dense as another will normally have approximately twice as great shrinkage and twice as great crushing strength, other things being equal, as shown in Figs. 7 and 8, respectively. Bending strength, on the other hand, increases more rapidly than the density. One piece twice as dense as another would have almost two and one-half times the bending strength. Other properties, such as hardness, increase still more rapidly as the density increases. One piece twice as dense as another would be almost five times as hard.

Relation between Summerwood and Density.—Summerwood is the dark-colored portion of the yearly growth ring and is put on during the latter part of each growing season. Its fibers are thicker walled than those of the lighter-colored springwood.

Tests made on a number of small pieces of summerwood and springwood whittled out separately from wide-ringed pieces of loblolly pine showed the strength in compression parallel to the grain and the density of the summerwood to be very nearly twice that of the springwood. It is evident, therefore, that the more summerwood present in a piece the greater will be the density and the higher its strength properties.

Thus, density serves as an excellent index of the strength properties of wood. This is true of different pieces of wood from the same species,

as well as pieces from different species. Density, however, is a factor that cannot be determined from ordinary inspection, so it becomes necessary to find some method of estimating it. Although density is the best indication of the strength of clear wood of all species, density measurements cannot readily be applied to domestic species other than south-



(*Courtesy Forest Products Laboratory.*)

FIG. 8.—Relation of maximum crushing strength in compression parallel to grain to specific gravity.

ern pine and Douglas fir, because density cannot be determined visually. An actual density or specific-gravity determination would have to be made. Fortunately, in southern pine and Douglas fir, density can be quite readily estimated from the proportion of summerwood in the piece.

An important point in connection with estimating density from the proportion of summerwood is the contrast in color between the summerwood and springwood. Numerous tests have shown that if the contrast in color between the two is not pronounced, the wood is not so strong as that with normal contrast between springwood and summerwood. In Douglas fir, however, there is not so much variation in the contrast between springwood and summerwood as in southern pine. For this reason, a requirement in Douglas fir that the contrast between springwood and summerwood be sharp, might exclude much material of an entirely satisfactory character. Consequently, it becomes necessary in drawing up the summerwood requirement for high-grade southern pine to include also a requirement for sharpness in contrast between summerwood and springwood, except in cases where the proportion of summerwood considerably exceeds the required minimum. Tests and trials under commercial conditions have demonstrated that the requirement of one-third summerwood in the annual rings assures high-grade material, provided certain limitations of defects also are imposed.

Density Measurement.—The density rules for Douglas fir and southern pine are described on pages 93 and 94. In estimating density from summerwood, it would be manifestly impracticable from a standpoint of time for an inspector to consider the whole cross-section of the larger-sized timbers. It would also be impossible in a large number of cases for him to estimate accurately summerwood in the outer portions of the piece, on account of the fineness of the rings.

To avoid this difficulty, it has been decided to use, in southern pine, the zone including the third, fourth, and fifth inches from the center for estimating the summerwood. The growth at this point is relatively wide and the summerwood is more easily estimated than at any other place in the cross-section. Measuring on the third, fourth, and fifth inches will give practically the same results as far as summerwood is concerned as any 3 in. farther out, and it is much easier to estimate the summerwood on the relatively wide rings.

In Douglas fir the distance over which the summerwood percentage is measured varies with the size of the piece, because of the nature of the Douglas-fir growth. A measurement taken over the third, fourth, and fifth inches from the pith in Douglas fir might not be at all representative of the best timber that the fir log contained, because the density may increase to a maximum 10 to 12 in. from the center of the tree.

In Douglas fir it frequently happens that the best timber is not produced until the tree is 24 in. in diameter. It is quite possible that the third, fourth, and fifth inches in Douglas fir may be the poorest in the whole stick and not representative of the cross-section.

If the southern-pine rule should be used for Douglas fir, only about 20 per cent of the structural timbers, as usually sawed, would pass the

classification, while nearly double this amount will pass the rule for Douglas fir.

The Douglas-fir rule, however, could be applied to southern pine without any special loss of efficiency or rejection of material, although it would be more difficult to estimate the summerwood in the southern pine by this rule, and the rule would be somewhat harder to apply.

In Douglas fir there is a close relationship between medium rate of growth, small knots, and dense material. Medium rate of growth in Douglas fir is most likely to produce dense timbers. This is not the case in southern pine.

The question will naturally arise as to how to determine whether or not one-third or more summerwood is present without making actual measurements.

In the first place, the quantity one-third lends itself more readily to underestimation than to overestimation by eye, because the dark band looks narrower in proportion than the light band. To have exactly one-third summerwood the springwood band must be just twice as wide as the summerwood. A fairly accurate estimate of summerwood percentage will result from a comparison of the width of the two portions of a number of rings on the smooth end surface of a piece. In addition, the contrast in color between the springwood and summerwood must be distinct. There are certain other provisions of the density rule relating to place where measurement is to be made, but these can readily be kept in mind.

Apparent Density Not Always True Density.—There are cases where heaviness in some pieces of wood might be mistaken for density, but this would not occur if density was estimated by means of summerwood rather than by means of feel or weight. A piece may be heavy because of its moisture content or because of resin. These conditions, of course, do not represent true density. Another type of structure found in many softwood species which gives the impression of density is compression-wood. This is commonly characterized by crescent-shaped, dull-brown rings, in which there is little contrast in color between springwood and summerwood, and in which there is also an apparent "blurring." Compression-wood is low in bending strength and toughness and should be avoided for purposes in which strength is important.

Low Density Frequently is Desirable.—In broadly considering the properties of wood, it should be noted that some pieces of each species are of high density, others of low density, and still others intermediate. Although the advantages of high density where hardness and other strength properties are required have been brought out, it should be remembered that low density, fortunately, is advantageous for certain other requirements. The fact that there are places where softer and less dense materials are preferable offers an outlet for wood which does not

come under the density classification. Dense pieces have the disadvantage that they split more readily in nailing and check more in drying than the lighter pieces and are somewhat harder to work.

High density is particularly desirable in material to be used for load-bearing purposes. Low density, on the other hand, is to be preferred in material for use for heat-insulation purposes and millwork, where strength properties are not of primary importance, but where a larger volume of air space in the wood or ease of working is desirable.

MOISTURE

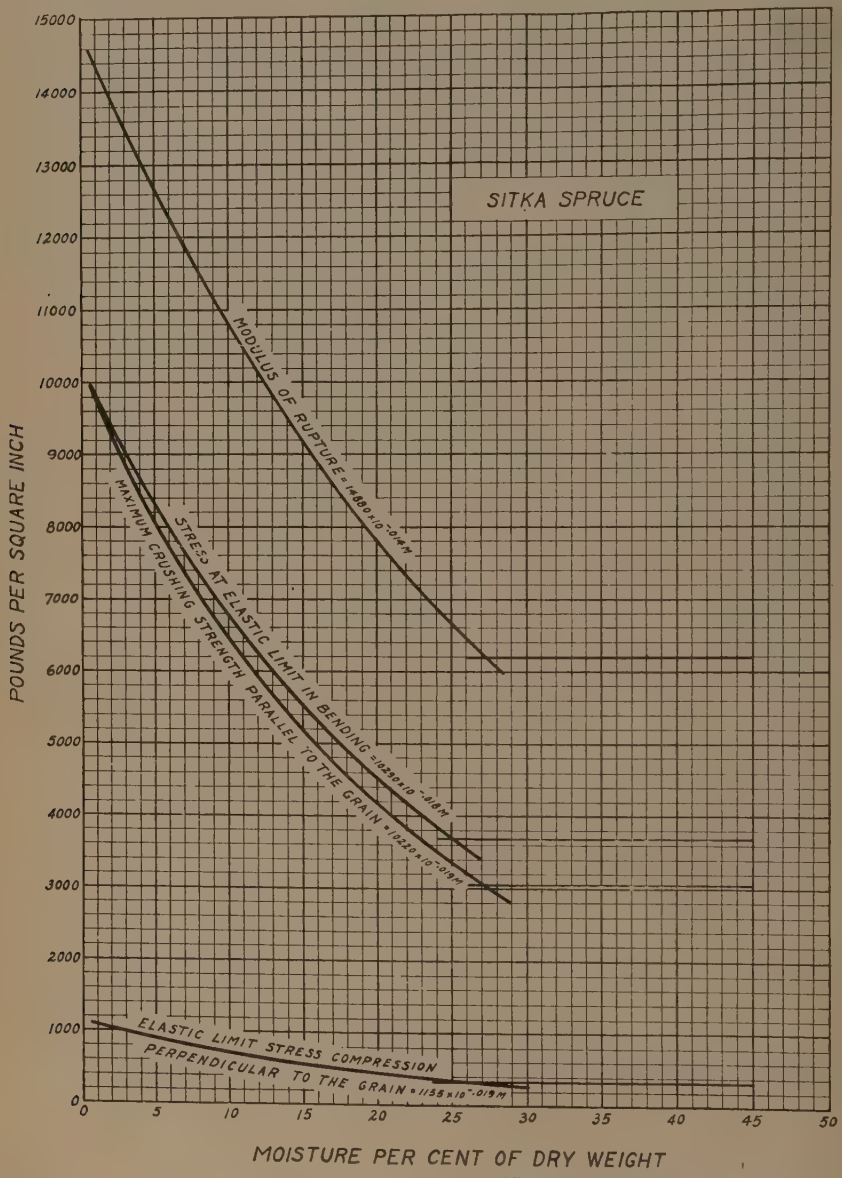
It has been found from extensive series of tests that the strength of wood is influenced not only by density, or the wood per unit volume, but also by its moisture content. Moisture, of course, affects some of the other properties of wood, also. The main objects of seasoning are to increase the durability of the wood in service, to prevent excessive shrinking and checking, to prevent it from staining, to decrease its weight, and to increase its stiffness and strength.

Moisture content is the weight of water contained in the wood, expressed in percentage of the oven-dry weight of the wood. Moisture content is determined by weighing a small section of the test specimen (which should be cut from the board at a point not less than 2 ft. from the end) and drying it at 100° C., in freely circulating air until its weight becomes constant. The loss of weight is then divided by the dry weight to give the proportion of moisture, and this is usually expressed in percentage. For example, if original or green weight is 180 grams, and oven-dry weight is 150 grams, the loss of weight is 30 grams, and $(30 \div 150) \times 100 = 20$ per cent = moisture content. Besides water, therefore, "moisture," as determined, includes any other substances which may be in the wood which are volatile at 100° C.

The various species differ widely as to the amount of moisture contained in the wood of the living tree. For example, white ash and black locust are always comparatively dry (about 40 per cent moisture): black ash has about twice, the various oaks from one and one-half to three times, and chestnut and buckeye some three times as much water as white ash. The coniferous species also show a wide range in moisture content. White cedar and Douglas fir have from 25 to 55 per cent moisture, and cypress and white fir contain large amounts, individual pieces of the latter species sometimes having as much as 300 per cent when freshly cut.

Moisture content sometimes varies with the position in the tree. Most coniferous species have a large proportion of moisture in the sapwood and a much smaller proportion (sometimes as low as 25 per cent) in the heartwood. In some the heartwood is very wet at the base of the tree but comparatively dry higher up. Most hardwoods, or broad-leaved species, show a fairly uniform distribution of moisture throughout the tree.

Moisture affects the strength of structural timbers both directly and indirectly. The direct effects of loss of moisture is the stiffening and strengthening of the wood fibers; small pieces, when dried to a low



(*Courtesy Forest Products Laboratory.*)

Fig. 9.—Relations between strength and moisture content of Sitka spruce.

moisture content, sometimes increase in strength as much as 200 per cent (see Fig. 9). Indirectly, however, the drying process often produces

checks and further develops shakes, the weakening effects of which more than counterbalance any gain in the strength due to seasoning. So, while the effect of moisture on the strength of small clear pieces is very marked, in large timbers ordinarily used for structural purposes the injury resulting from defects induced in the drying process frequently offsets any increase in the strength of the wood itself. In any heavy structural material it is not considered good practice to allow higher stresses for dry than for green material.

Moisture conditions of service have an important bearing on decay and checking and, therefore, upon the strength of the wood. The effect of moisture on strength has already been mentioned. Studies have shown the strength of large timbers to be about the same in a green as in an air-dry condition and have also shown the amount of increase in strength with drying that can be expected in higher grades of dimension and in small, clear material. The loss of moisture accompanying seasoning differs in its effect upon strength according to the size of the material. Clear wood in small sizes increases in strength with loss of moisture, the increase being much greater for some properties than for others. Thus, compressive strength of pieces of 2 by 2 in. in cross-section may increase 100 per cent or more from the green to the air-dry condition, and bending strength 50 per cent or more; whereas impact and work-to-rupture values seldom increase by more than 20 per cent and may even show a loss in some species.

With larger pieces, the checking which accompanies drying increases in severity, especially as knots increase in number and size. Thus, clear dimension material 2 to 4 in. thick increases in strength about 25 per cent on drying, but the common grades increase only about 8 per cent. Owing to injury from checking, the lower grades of large timbers and about 25 per cent of large timbers of high grades show no increase in strength with drying, although the average strength of large timbers is raised slightly.

Timber in wet or damp locations is subject to deterioration from decay. Under such conditions, lower stresses are recommended in order to offset the effect of depreciation and to avoid the damage which might result from failure to replace the member frequently.

Moisture Affects Volume of Wood.—Other direct results of changes in moisture content are shrinkage and swelling. Water exists in wood in two conditions, namely, as free water contained in the cell cavities and as water absorbed in the cell walls. When wood contains just enough water to saturate the cell walls, it is said to be at the fiber saturation point. Any water content in excess of this is in the form of free water in the cell cavities. Removal of the free water has no apparent effect upon the properties of the wood except to reduce its weight, but as soon as any of the absorbed water is removed the wood begins to shrink. Since the free water is the first to be removed, shrinkage or changes in

strength properties (see Fig. 9) do not begin, as a general rule, until the fiber-saturation point is reached. For most woods, the fiber-saturation point corresponds with a moisture content of from 23 to 30 per cent of the dry weight of the wood. When wood is dried below the fiber-saturation point, shrinkage begins. It continues until the moisture is all driven off. Shrinkage along the length of a piece of wood of normal structure is very small, but at right angles to the grain it is much greater and varies from 2 or 3 per cent to as much as 20 per cent. The average decrease in volume of a piece of green lumber when brought to the average air-dried condition of 12 to 15 per cent moisture is about 5 per cent.

Moisture Specification.—There is an active movement underway among the associated softwood interests to establish moisture-content definitions or specifications, so that lumber may be purchased according to a definite seasoning grade or at least with a definite understanding concerning its moisture content. This movement would place the seasoning specification on a par with the grade specification. Of course, the seasoning grade under which lumber is purchased would be dictated by the use to which the lumber is to be put. The conditions under which lumber is used may be divided into three broad classes: (1) interior finish of heated buildings; (2) rough or framing lumber; (3) uses which require no seasoning whatsoever. The first requires well-kiln-dried lumber and might be said to include stock between 6 and 12 per cent moisture content; the second includes either air-dried or kiln-dried stock and might range from 12 to 20 per cent moisture content; and the third, green lumber with a moisture content greater than 20 per cent.

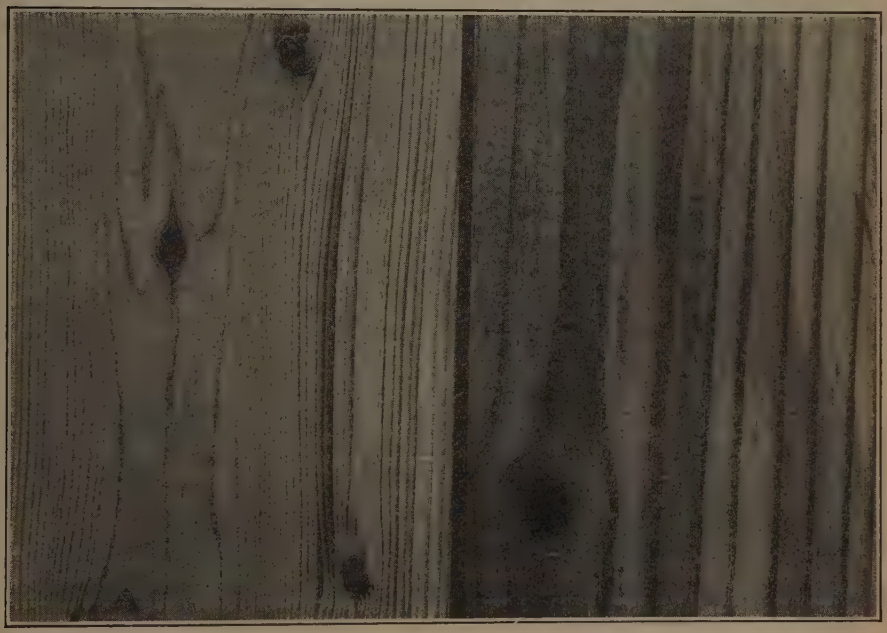
The matter of seasoning definitions or specifications for hardwoods is much more complicated. A large amount of hardwood lumber is redried at the point of consumption. That which is purchased seasoned for use is bought on specification or under special agreement regarding its moisture content. Practically all hardwood lumber used in buildings goes into finish and flooring and should be thoroughly kiln dried.

DEFECTS

A defect in a timber is any irregularity occurring in or on the wood that may lower any of its strength properties. One of the fundamental characteristics of wood is the difference in its strength with and across the grain. Because of the arrangement of the elements of which wood is composed, its resistance to stress varies with the direction of the stress relative to the grain of the wood. It is this difference in the strength with different angles of the grain that accounts for the serious weakening effect of most defects. The injuries resulting from defects are due primarily to four fundamental causes: (1) the characteristic difference in the strength of wood with and across the grain; (2) separation of the wood fibers; (3) breaking of the wood fibers; and (4) disintegration of the wood substance.

Kinds of Defects.—No kind of tree produces lumber entirely free from defects and blemishes. The same irregularities in the wood, natural and accidental, are likely to occur in all species; and in all woods used for the same purpose the effect of a certain defect on strength and quality is about the same.

Knots are probably the most common of the natural defects in lumber (see Figs. 10, 11, 12, and 13). Most branches of forest-grown trees originate near the center of the trunk and grow in diameter and length as long as conditions are favorable. The branch end or knot in the trunk is, therefore, typically shaped like a cone with its apex toward the pith.



(Courtesy Forest Products Laboratory.)

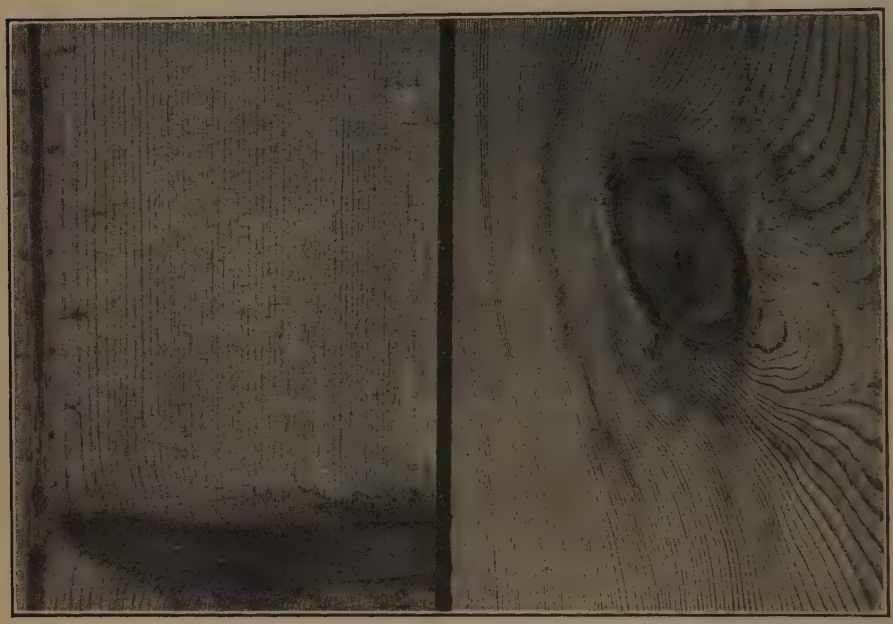
FIG. 10.—Left: pin knots. Right: small knot.

A branch end when sawed through appears on a flat-grain surface as a round knot and in vertical-grain material as a spike knot. Many of the lower branches in forest-grown trees die and fall off when the upper branches cut off too much of their light. As the tree continues its diameter growth, new wood surrounds the stubs of the old branches. When the log is cut up these covered stubs are found in the lumber as encased knots.

The damage done by knots is not due to the knot material's being inherently weaker than normal wood but to the combined operation of several factors, the most important of which are cross-grain and checking. In order better to understand the injury, we must consider the effect of

knots in distorting the grain (see Fig. 14). Since knots are formed by the wood fibers of the main body of the tree running out into the limb and cross-grain is developed, upon the death of a limb the fibers cease to grow out into it, and the new wood which begins to encase the knot shows a decrease in grain distortion.

All trees do not have pitch streaks or pitch pockets (see Figs. 15 and 16), but such blemishes are found in the majority of softwoods. The pitch content often varies as much within a species as it does between species. A typical pitch pocket in southern pine may be shorter and



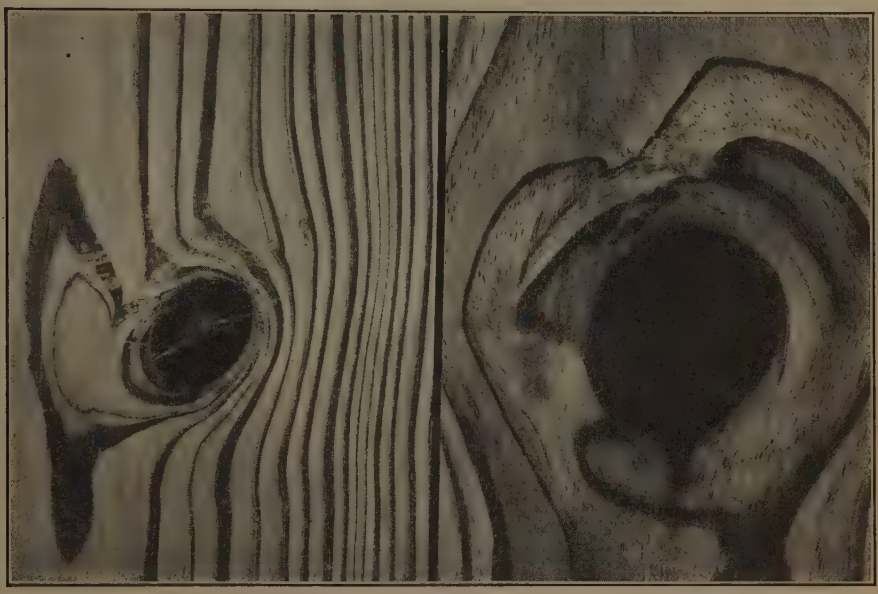
(*Courtesy Forest Products Laboratory.*)

FIG. 11.—Left: spike knot and pith. Right: encased knot (sound and oval).

wider than one in Douglas fir, but if it is equal in area it is practically equivalent in damaging effect.

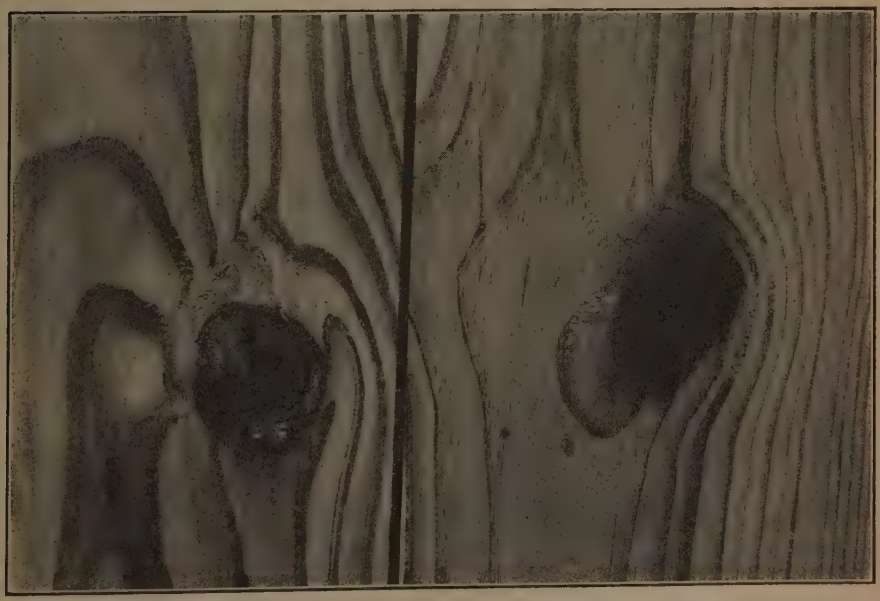
The same kind of blemish-producing accidents happen to all kinds of wood. Holes produced by the falling out of loose knots, by grubs, insects, birds, and by tools appear in all kinds of lumber (see Fig. 17). Fire scars are found in all species of trees.

Most woods are subject to the attack of decay-producing fungi which may work in heartwood or sapwood or in both. Checks, cracks, splits, casehardening, honeycombing, warping, and other seasoning defects are likely to be found in any kind of wood (see Fig. 18). Manufacturing defects, such as planer skips—the result of cup, bow, crook, and twist—



(*Courtesy Forest Products Laboratory.*)

FIG. 12.—Left: medium knot. Right: large knot, sound, intergrown, round, tight, water-tight.

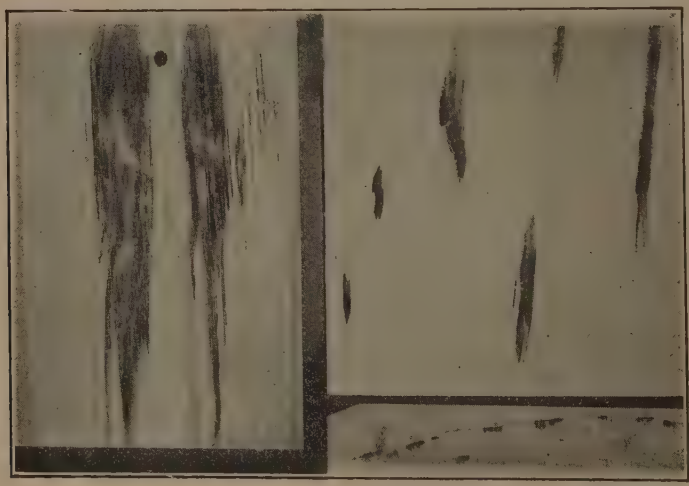


(*Courtesy Forest Products Laboratory.*)

FIG. 13.—Left: decayed knot. Right: pith knot.

(Courtesy Forest Products Laboratory.)

FIG. 14.—Knot showing characteristic difference in behavior of fibers on lower and upper sides of knot.



(Courtesy Forest Products Laboratory.)

FIG. 15.—Left: pitch streaks in southern pine. Right: mineral streaks on face and cross-section of board of sugar maple.

may occur in all species. All lumber may have cross-grain, shake, and stain.

Certain defects may be more prominent in one wood than in another, but there are more points of similarity than dissimilarity in the defects present in different species. This fact was made use of in drawing up the rules in Chap. II for the grading and selection of softwood lumber, now generally known as the American Lumber Standards. These rules recognize certain defects as the equivalent of others and limit the size of

(*Courtesy Forest Products Laboratory.*)

FIG. 16.—Pitch pockets cut through tangentially (upper left), radially (upper right) and transversely (bottom).

these defects. They are applicable to all softwoods and might be extended to cover many hardwoods, used for the same general purposes.

Checks and shakes are local wood failures or weaknesses which occur either in the living tree or in lumber. Checks are lengthwise separations along the fibers and across the growth rings (see Figs. 18 and 19); shakes are lengthwise separations between and parallel to the growth rings (see Figs. 20 and 21). Checks are commonly due to seasoning; shakes seldom develop unless they are present to a certain degree in the standing tree.

The checks which develop with seasoning are due largely to drying of the wood from the outside toward the center. Drying is accompanied by shrinkage, and when, as is usually the case, circumferential or tangential shrinkage differs greatly from radial shrinkage, checks, or at least severe shrinkage stresses, are inevitable in pieces which contain the pith, regardless of uniformity of drying. When the exterior of a piece of wood dries

(*Courtesy Forest Products Laboratory.*)

FIG. 17.—Left: pinworm holes. Right: grubworm holes.

more rapidly and shrinks more than the interior, progressively increasing stresses which often result in failure are set up. Because of the greater difference between the moisture content of interior and exterior portions of large timbers as compared with small pieces, the rupture is more severe in the larger sizes. The failures follow the direction of the grain and consist of longitudinal separations of the wood fibers, mostly across the annual growth rings as checks.

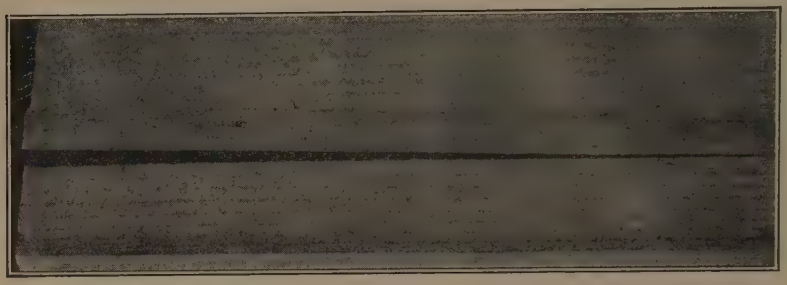
(*Courtesy Forest Products Laboratory.*)

FIG. 18.—(*a*) End and through checks, (*b*) honeycombing, (*c*) medium surface checks, (*d*) large surface checks.

(*Courtesy Forest Products Laboratory.*)

FIG. 19.—Illustration of the injurious effect of checking in and surrounding knots.

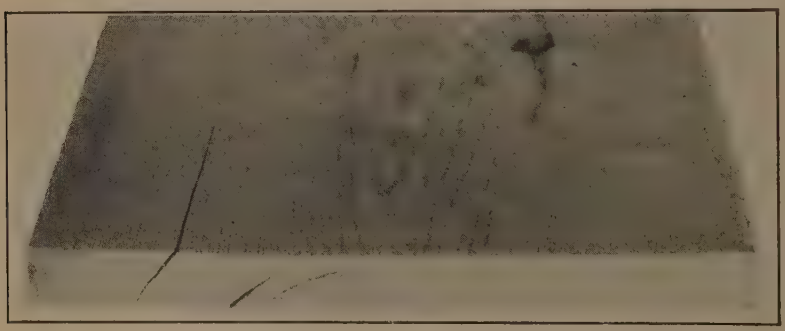
Cross-breaks are tension failures usually resulting from local abnormal longitudinal shrinkage. Such shrinkage is characteristic of "compression" wood (Figs. 22 and 23), which can usually be detected in Douglas fir and southern pine by the absence of contrast between springwood and summerwood. Compression failures (Fig. 24) occur as the result of



(Courtesy Forest Products Laboratory.)

FIG. 20.—Open shake.

stresses in the standing trees due to wind or other causes, stress developed when the tree falls, and, at times, rough handling of logs or timber. They are limited in extent and occurrence. They may be sufficient to reduce greatly the strength of small pieces and yet be difficult to detect. Usually, however, they will be evident on careful inspection when of sufficient extent and development to affect seriously the strength of large timbers.



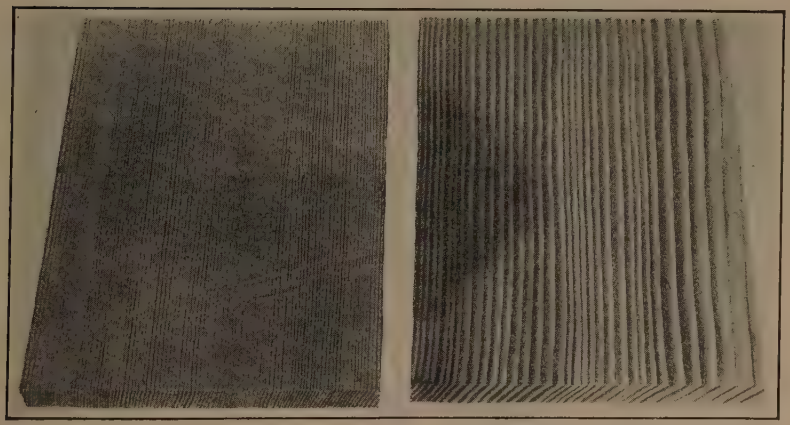
(Courtesy Forest Products Laboratory.)

FIG. 21.—Shake in a flat-grain board.

Cross-grain is the general term to describe any departure of wood cells or fibers from a direction parallel to the axis of the pieces. There are a number of kinds, as spiral, diagonal, wavy, dip, curly, and interlocking grain (see Fig. 25). Grading-rule limitations on cross-grain in structural timber are intended to apply only to spiral and diagonal grain. The other forms are usually due to knots, and knot limitations can be depended upon to control them.

(*Courtesy Forest Products Laboratory.*)

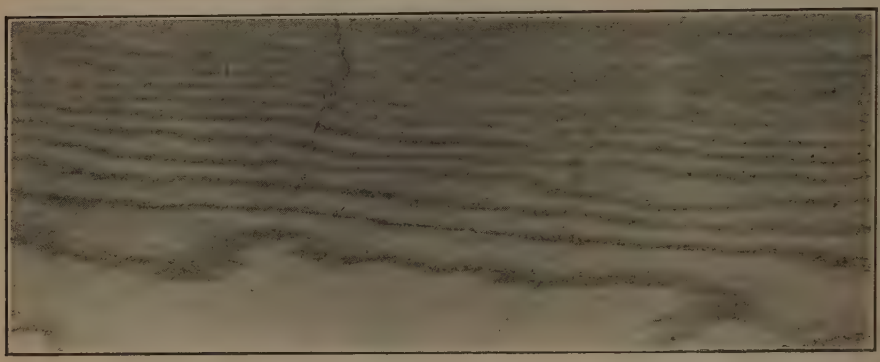
FIG. 22.—Cross-section of log showing compression wood—the dark, wide rings on the left side.



(*Courtesy Forest Products Laboratory.*)

FIG. 23.—Left: normal wood. Right: compression wood.

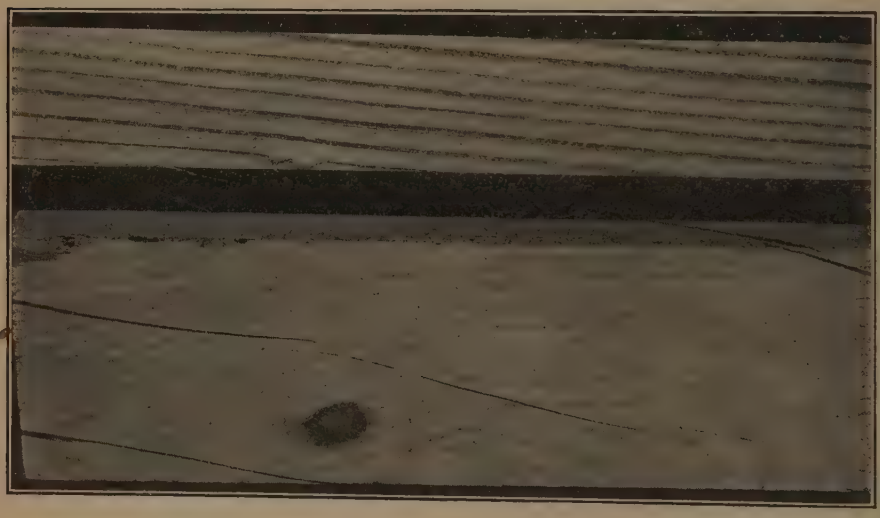
Decay is disintegration of wood substance due to the action of wood-destroying fungi. This action consists in a breaking down of cell walls, resulting in a weakening effect even when the presence of fungus cannot



(*Courtesy Forest Products Laboratory.*)

FIG. 24.—Compression failure.

be detected visually. Decay, therefore, is an important factor in determining the strength of wood, but its total injurious effect is difficult to measure because the amount of decay visible on the exterior is not a satisfactory indication of the extent to which the strength of the wood is



(*Courtesy Forest Products Laboratory.*)

FIG. 25.—Diagonal grain (top), spiral grain (bottom).

affected. Certain types of decay sometimes continue their destructive action after the timbers have been placed in use. It is, therefore, necessary to limit decay more rigidly than would seem justified by test.

The defects enumerated are the essential ones to control in specifications intended to establish definite strength values. There are, however, others that often give indication of the presence of more injurious defects and so may be of considerable assistance in grading. Thus, bark pockets and gum spots or streaks are indications of concealed knots; collapse, of severe drying treatments and probable loss of inherent strength; pitch, of shakes and of erratic strength; discoloration and insect holes, of decay attack; and warping, of cross-grain.

Effects of Defects on Strength Properties.—While density and moisture have an important effect upon the strength of wood, the greatest variations in strength are caused by defects.

In view of their importance, it would appear that the necessity of investigating their effect on the strength of structural members would arise almost simultaneously with the use of wood in construction. The explanation of the fact that real research started as late as 1900 lies in the abundance of clear high-class timber available during the early history of this country. There was no need of seriously considering the effect of defects, so long as there was an abundance of high-class timber to meet the drastic requirements of old timber specifications and grading rules, which called for timbers free from splits, shakes, checks, loose or decayed knots or other defects which might impair their strength or durability. In other words, they called for practically clear material.

As the virgin timber began to disappear from the great wooded areas of our country, it became more and more difficult to meet these rigid specifications and to obtain high-class timber. New rules and specifications appeared. These rules were patterned after those that had been developed for yard and factory lumber in which appearance rather than strength was the important factor. Thus, timber with high strength values was often placed in low grades because of the presence of a defect which marred the appearance but had little effect on the strength, while other timbers with partially concealed defects were placed in top grades. For example, timbers in which shakes appeared on the face were degraded, but timbers with much larger and more injurious shakes which showed only on the ends were accepted. Here, again, is found a wide difference in the strength of timber of the same grade and no assurance of a minimum strength upon which safe and economical working stresses can be based.

The first step in the study of the effect of defects on strength is to determine the character and occurrence of defects and their effect on the elementary stresses of tension, compression, and shear. This involves a study of the nature and cause of defects and the fundamental method in which they affect the elementary stresses. With this knowledge as a basis, it becomes possible to analyze the stresses in a beam, separate them

into elementary or direct stresses, and determine the cause and amount of injury resulting from defects.

Some defects affect all of the fundamental strength properties, *viz.*, tension, compression, and shear; others affect but one of the properties, while still others cause injury by their combination with other defects. The manner in which these defects and their combinations affect the strength properties of wood is of fundamental importance in the grading of structural timbers.

Strength in tension is affected most seriously by cross-grain, checks, knots, cross-breaks, and compression failures.

The ratio of the strength in tension with and across the grain of wood is larger than for compression and shear, being about 25 to 1 for small, clear, green specimens and as high as 45 to 1 for air-dry specimens. The amount of injury which will result from cross-grain depends upon the angle the grain makes with the axis of the piece. Even a slight departure from straight grain is a source of weakness, although it does not become very apparent until a slope of 1 in 25 is reached.

The separation of the wood fibers by checks has little, if any, effect upon the strength in tension when the load is applied in line with the fibers. On the other hand, when the load is applied perpendicularly to the fibers, their separation by checks will cause a direct reduction of the area acting in resistance to tension and, consequently, will reduce the strength. The reduction of tensile strength from checking varies between these two extremes, becoming more and more serious as the angle of grain increases. In short pieces, checking may sometimes reduce to zero the area acting in resistance to tension by actually separating the piece into parts.

The weakening influence of knots on tensile properties is almost entirely due to cross-grain and the checking which is introduced. Cross-grain around a knot can be measured on the surface, but that within the knot itself cannot be judged in this way. Usually, however, the grain of a knot is at such a wide angle with the axis of the piece that its strength at best can only be considered as the strength of wood perpendicular to grain. Checking, as a rule, will destroy even this, and the effect of the knot proper becomes the same as that resulting from the removal of an equal amount of wood; and, in addition, the influence of the checking and irregular grain surrounding the knot must be taken into account.

The shape and other characteristics of a sound knot have little influence upon the amount of injury to be expected, since the injury is dependent to a large extent upon the amount of grain distortion. There is very little difference between the reduction of tensile strength caused by knot holes or encased knots and that caused by intergrown knots. The injury from a lack of bond around an encased knot, or the absence of material in a knot hole, is actually less than the injury resulting from the greater

distortion of grain around an intergrown knot and from the checking which accompanies it. The amount of grain distortion is dependent upon the diameter of the limb which caused it, but its increase is greater than the corresponding increase in the diameter of limb.

Shakes, like checks, have no effect on tensile properties when the load is applied in line with the grain, but any separation of the annual rings would, of course, destroy the tensile strength across the grain. Cross-breaks and compression failures, on the other hand, reduce the strength when the stress is parallel to the grain.

The effect of cross-grain and knots is much less in compression than in tension. The effect of checks and shakes is confined largely to causing an unequal distribution of strength; and this results in a reduction of strength through the overstressing of some of the fibers before others.

The compressive strength of wood parallel to the grain is from six to ten times that perpendicular to the grain. This ratio is about the same for both the green and the air-dry material and is much smaller than that in the case of tension. While the reduction in compressive strength starts with the slightest deviation of the grain, it does not become appreciable until the grain is at a slope of approximately 1 to 10. This difference in the effect of cross-grain accounts primarily for its smaller injury in compression.

Under the action of compression parallel to grain, checks tend to close up, and the entire cross-section is under stress. The stresses, however, are not of uniform intensity, and failures, therefore, occur at somewhat lower average loads than if the checks were not present. In fact, checks sometimes do not close until failure has started.

The weakening effect of a knot, in compression as in tension, is due primarily to the cross-grain that accompanies it. The weakening effect of cross-grain, however, is considerably less for compression than for tension, and checking in and around the knot is also less injurious. Quite frequently, a part or all of the strength across the grain is developed in a knot resisting compression, even when the knot is checked. The net result is a weakening somewhat less than would occur by the removal of the knot proper.

Reduction in shearing strength is due almost entirely to the presence of shakes and checks; the presence of knots and cross-grain exerts but little influence in this respect. In fact, knots and cross-grain break up the continuity of checks and thus tend to reduce their injurious effects in shear.

Weakening in shear from checks and shakes consists in a direct reduction of the area acting in resistance to shear. Shakes, moreover, are usually accompanied by a general weakness in bond between the annual growth rings which seriously affects the shear strength.

SOME POPULAR BELIEFS ARE UNFOUNDED

Prejudice exists in certain quarters against the use of timber cut from dead trees, and some purchase specifications insist that only timber cut from live trees will be accepted. As a matter of fact, when sound dead trees are sawed into lumber, and the weathered or charred outside is cut away, the lumber cannot be distinguished from that cut from live trees by any method known except that the lumber from dead trees may be partly seasoned when sawed.

All the information available indicates that lumber cut from insect- or fire-killed trees is just as good for any structural purpose as that cut from live trees of similar quality, provided the wood has not been subsequently injured by decay or further insect attack. If a tree stands on the stump too long after it is killed the sapwood is likely to become decayed, checked, or badly infested by wood-boring insects; and in time the heartwood also will be similarly affected. The same thing is true of logs cut from live trees and not properly cared for. Until the wood becomes affected by these destructive agents, dead-tree wood is just as strong as sound live-tree wood.

In considering the subject it may be useful to remember that the heartwood of a living tree is entirely matured and that in the sapwood only a comparatively few cells are living. Most of the wood cut from trees is dead, therefore, regardless of whether the tree itself is living or not. Such being the case, purchase specifications, instead of providing that material must not be from dead trees, should state that material showing evidence of decay or insect infestation exceeding a specified limit will not be accepted.

Dry Rot.—The term *dry rot* is applied by many persons to any dry, crumbly rot. Thus loosely used, the term actually includes all brown decay in wood.

In the more limited sense in which pathologists use the term *dry rot*, it applies only to the work of certain fungi. These fungi gain their distinction from the fact that they are frequently found growing in timbers without any apparent moisture supply; in reality, they do not grow without moisture and are as powerless as any other fungus to infect thoroughly dry wood. Given moist wood in which to germinate, they are able to make their way surprisingly long distances in dry timbers, drawing the water they need from the moist wood through a conduit system of slender, minutely porous strands. *Merulius lachrymans* and *Poria incrassata* are typical dry-rot fungi.

Other fungi produce brown cubical rot similar to dry rot. Wood in the advanced stage of these rots is shrunken, yellow to brown in color, and filled with radial and longitudinal shrinkage cracks roughly forming cubes. In many instances, these cracks are filled with a white, felty mass.

The decayed wood is so brittle and friable that it can easily be crushed into powder.

Virgin and Second Growth Not Strength Criterions.—Specifications often call for virgin-growth or second-growth timber, yet the terms are without fixed significance, and the material when delivered cannot be positively identified as belonging to one class or the other.

Virgin growth, also called *first growth* or *old growth,* means timber which grew up in a standing forest under conditions of active competition for sunlight and moisture.

Second growth, when applied to a forest stand, usually means timber in which the main growing period occurred under conditions of lessened competition, after all or a portion of the original stand had been removed by cutting, fire, wind, or other means. In connection with individual trees, the term is used to mean any tree growing under conditions approximately those that would produce a second-growth stand. To the wood user, second growth means material cut from either of these sources. In general, the term is associated with the idea of a second crop of timber, though specific applications may vary.

Virgin growth is generally thought of as slow-growing timber, while second growth, due to more favorable conditions, is relatively rapid. A faster rate of growth is evidenced by wider annual rings. These are popularly supposed to indicate stronger and tougher wood in the hardwoods, such as ash, hickory, elm, and oak; and weaker and brashy wood in the conifers, such as pine and fir. Hence, for uses in which strength and toughness are essential, second growth is sought among the hardwoods, whereas in conifers virgin growth is desired.

As a second-growth forest attains maturity, the rate of growth slows down, so that the annual rings may be no wider than in virgin-growth timber of the same size. On the other hand, when a slow-growing suppressed forest tree is freed by removing the neighboring trees, it may grow rapidly for a long period. There it is possible to have some wood with the characteristics of virgin growth and some with those of second growth in the same tree. Furthermore, individual trees in a virgin-growth forest may have the characteristics of second growth throughout, and *vice versa.*

Instead of broadly specifying "second growth" or "virgin growth" or depending upon requirements concerning the width of annual rings to secure good material, it is advisable to rely upon density as a guide to quality.

Effect of Time of Cutting Timber on Durability of Wood.—Many of the theories which have been advanced regarding the durability of wood attribute too much importance to the time of cutting. As a matter of fact, the time of cutting has very little effect upon the durability, or other properties, if the timber is properly cared for after it is cut. The

method of handling logs at different times of the year, however, does influence their durability.

Piling and other rough products cut in late spring and early summer are more likely to be attacked by insects and fungi, because the wood is freshly cut and in the most favorable condition for attack at a time when insects and the spores of fungi are most active. Seasoning also proceeds more rapidly during the warmer months and may cause excessive checking. If the wood is peeled when cut and piled openly on skids for seasoning, opportunity for decay will be reduced to a minimum, but checking will not be retarded. In no case should the wood be allowed to lie in direct contact with the ground. If checking is an important consideration, it can be reduced somewhat by locating the piles in a shaded but dry place. The bark peels most easily in spring. It can be removed at any other time of the year, but the labor and expense will probably be greater.

Timber cut in late fall and winter seasons more slowly and with less checking than during the warmer months. When proper storage or handling is impracticable, winter cutting is best. Fungi and insects do not attack wood out of doors in cold weather, and by the time warm weather arrives, the wood is partly seasoned and somewhat less susceptible to attack. It is for this reason that winter cutting is advantageous, and not on account of a smaller amount of moisture or sap in the wood in winter, as popular belief has it. There is practically no difference in moisture content of green wood between winter and summer.

Comparative Strength of Air-dried and Kiln-dried Wood.—Some wood users claim that kiln-dried wood is brash and not equal in strength to wood that is air dried. Others advance figures purporting to show that kiln-dried wood is much stronger than air-dried. But some 150,000 comparative strength tests, made by the Forest Products Laboratory on kiln-dried and air-dried specimens of 28 common species of wood, show that good kiln drying and good air drying have the same effect upon the strength of wood.

The belief that kiln drying produces stronger wood than air drying is usually the result of failure to consider differences in moisture content. The moisture content of wood on leaving the kiln is generally from 2 to 6 per cent lower than that of thoroughly air-dried stock. Since wood rapidly increases in strength with loss of moisture, higher strength values may be obtained from kiln-dried than from air-dried wood. Such a difference in strength has no significance, since, in use, a piece of wood will come to practically the same moisture condition whether it is kiln dried or air dried.

It must be emphasized that the appearance of the dried wood is not a reliable criterion of the effect the drying process has had upon its strength.

The strength properties may be seriously injured without visible damage to the wood. Also, it has been found that the same kiln-drying process cannot be applied with equal success to all species. To insure uninjured kiln-dried material, a knowledge of the correct kiln conditions to use with a stock of a given species, grade, and thickness and a record showing that no more severe treatment has been employed are necessary.

STRENGTH GRADING

The primary purpose of the study of the effect of defects on the strength of timber is to obtain a fundamental basis for specifications and grading rules which will limit defects in accordance with their effect on strength. The efficiency of grading rules in separating timber into strength grades is dependent upon how closely they apply these fundamental principles, although in writing practical rules for structural grading it is necessary to depart somewhat from the ideal where every timber capable of sustaining the required load would be included in the grade.

The first grading rules to be based on strength tests were published in *United States Forest Service Bulletin* 108, "Tests of Structural Timbers." Provision was made for two grades of material. In applying these rules, a timber was graded on the basis of three volumes. Based on these rules, the American Society for Testing Materials adopted tentative specifications for grading structural timbers. The Southern Pine Association and West Coast Lumbermen's Association both prepared and published commercial grades based on American Society for Testing Materials' rules.

These commercial rules were not entirely satisfactory in theory or practice. The grading of timbers by sharply defined volumes was found to be difficult, and the abrupt change in allowable size of knots between volumes is not in accordance with the distribution of the stresses. Material of these grades was not generally used because of the price demanded for it and because economic conditions had not reached a point that prohibited the use of inefficient rules based on appearance or the grader's judgment.

The Forest Service, in the light of more recent tests, has revised the old rules and at the same time removed some of the practical objections to them. These revised rules were published in *United States Department of Agriculture Circular* 295.

Using the rules of *Circular* 295 as a basis, rules were worked up by a joint committee of the American Railway Engineering Association and the American Society for Testing Materials. These rules were first published as American Lumber Standards and then by the American Railway Engineering Association and the American Society for Testing Materials.

They have been somewhat amplified since first drafted, but have not been changed in any basic way.

They separate timbers into grades to which definite working stresses can be assigned, giving assured minimum values and are much more efficient than any previous commercial grading systems. The adoption and application of American Lumber Standards—with which the lumber industry is striving to conform—as a basis for standard structural grades will promote more economical use of our forest resources.

Engineers, architects, and other wood users, therefore, are urged to use in their specifications grading rules conforming to the requirements of the American Lumber Standards basic grades now being published by the Department of Commerce. These standards have been adopted by the industry in cooperation with distributors and consumers of lumber under the auspices of the Department of Commerce and are arranged with appropriate explanations, in Chap. II of this volume.

GRADE MARKING

As a further step to enable the consumer to use lumber more efficiently and to identify it after purchase, the principle of stamping lumber with a grade mark and a trade mark has been incorporated in the American Lumber Standards. A large number of lumber manufacturers are now grade-marking their products and the approval of all branches of the industry is indicated by the following resolution adopted by the General Lumber Conference held May 3, 1928:

> The producers, distributors, and consumers of lumber represented in general conference in Washington, May 3 and 4, at the invitation of the Secretary of Commerce, endorse the plan undertaken by the National Lumber Manufacturers Association for converting into nation-wide practice the nationally recognized principle of association trade and grade marking of American Standard lumber; will encourage its general support; and will urge wholesale and retail distributors and consumers in lumber to cooperate with the lumber manufacturers in securing the wide distribution and general use of association trade-marked and grade-marked American Standard lumber.

Lumber manufacturers are also guaranteeing the quality of lumber shipments by placing in each car of lumber a sealed envelope containing a certificate showing the grade and footage of the shipment. This envelope is addressed to the purchasing agent who thus receives a certified report of the contents of the car as loaded at the mill. The identity of the mill shipping the lumber is not shown except by a serial number issued by the Lumber Manufacturers Association of which the individual manufacturer is a member. The association alone has a record of the mill from which the lumber is shipped.

Several of the Lumber Manufacturers Associations have adopted this plan and it is possible for lumber consumers to secure, upon request, such assurance of quality and accuracy of shipments of lumber coming from all parts of the country.

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CHAPTER II

LUMBER GRADING, GRADE PROVISIONS, AND WORKING STRESSES

Originally, lumber was graded on one basis, largely that of appearance; but developments in the lumber industry and differences in the requirements of wood consumers have led to the adoption of rules for the grading of lumber in three separate and distinct classes. (1) yard lumber, (2) factory or shop lumber and (3) structural timbers. The improved sections of these grade and size standards, known as *American Lumber Standards*, are described in this chapter, and the underlying reasons for their adoption are discussed.

Yard lumber is graded primarily on appearance, as practically all lumber was at first. Factory lumber is graded on the percentage of clear cuttings which can be obtained from a given board. Both of these grade sections differ fundamentally from the third class in that their use is predicated chiefly on experience and on empirical or "rule-of-thumb" methods, in contradistinction to the engineering formulæ and unit stresses employed where structural material is concerned. Structural grades are based primarily on strength properties.

Structural material is usually thought of in sizes 6 in. and larger. This does not mean that unit stresses are never considered when lumber under 6 in. is used. On the contrary, floor joists of 2- and 3-in. stock should always be checked for unit stresses, while such items as sheathing, flooring, and millwork are subjected to unknown and indeterminate stresses, and their dimensions are governed principally by experience.

Structural grades differ from yard grades in one essential particular: A yard grade is based on an assortment of material from the grade below to the grade above. A structural grade may consist of a similar assortment, but the strength value of the grade is dictated by the low line pieces of the grade, and structural grades must be so written that no piece will fall below the working strengths recommended for the grade.

USE CLASSIFICATION

Lumber is the product of the saw and planing mill not further manufactured than by sawing, resawing, and passing lengthwise through a standard planing machine, crosscut to length and matched.

Lumber is classified as (*a*) yard lumber, (*b*) factory or shop lumber, and (*c*) structural timbers. Different grading rules may apply to each class of lumber.

a. Yard Lumber.—Lumber that is less than 5 in. in thickness and is intended for general building purposes. The grading of yard lumber is based upon the use of the entire piece.[1]

b. Factory and Shop Lumber.—Lumber intended to be cut up for use in further manufacture. It is graded on the basis of the percentage of the area which will produce a limited number of cuttings of a specified, or a given minimum, size and quality.

c. Structural Timbers.—Lumber that is 5 in. or over in thickness and width. The grading of structural timbers is based upon the strength of the piece and the use of the entire piece.

SIZE CLASSIFICATION

Yard Lumber

Strips.—Yard lumber less than 2 in. thick and under 8 in. wide.

Boards.—Yard lumber less than 2 in. thick, 8 in. or over in width.

Dimension.—All yard lumber except boards, strips, and timber; that is, yard lumber 2 in. and under 5 in. thick and of any width.[1]

Planks.—Yard lumber 2 in. and under 4 in. thick and 8 in. and over wide.

Scantlings.—Yard lumber 2 in. and under 5 in. thick and under 8 in. wide.

Heavy Joists.—Yard lumber 4 in. thick and 8 in. or over wide.

Structural Timbers

Timbers.—Lumber 5 in. or larger in least dimension.

MANUFACTURING CLASSIFICATION

Manufactured lumber is classified as (*a*) rough, (*b*) surfaced, and (*c*) worked.

a. Rough Lumber.—Undressed as it comes from the saw.

b. Surfaced Lumber.—Lumber that is dressed by running through a planer. It may be surfaced on one side (S1S), two sides (S2S), one edge (S1E), two edges (S2E), or a combination of sides and edges (S1S1E), (S2S1E), (S1S2E), or (S4S).

c. Worked Lumber.—Lumber which has been run through a matching machine, sticker, or molder. Worked lumber may be (1) matched, (2) ship-lapped, or (3) patterned.

1. *Matched Lumber.*—Lumber that is edge dressed and shaped to make a close tongued-and-grooved joint at the edges or ends when laid edge to edge or end to end.

2. *Ship-lapped Lumber.*—Lumber that is edge dressed to make a close rabbeted or lapped joint.

3. *Patterned Lumber.*—Worked lumber that is shaped to a patterned or molded form.

[1] Dimension (planks and joists) to be used where working stresses are required should be considered and graded as structural material (See pages 90 to 114).

COMMERCIAL NAMES FOR LUMBER AND TIMBER CUT FROM THE PRINCIPAL SPECIES OF SOFTWOODS

The following standard commercial names for lumber cut from the principal species of softwoods shall be used in the formulation of lumber grading rules and in the construction of contracts and the terms of purchase and sale of American Standard lumber.

Standard Commercial Name	Botanical Name
Cedars and Junipers	
Alaska cedar	*Chamaecyparis nootkatensis*
Eastern red cedar	*Juniperus virginiana* (also *Juniperus lucayana*—Southern red cedar—and *Juniperus mexicana*—Mountain juniper)
Incense cedar	*Libocedrus decurrens*
Northern white cedar	*Thuja occidentalis*
Port Orford cedar	*Chamaecyparis lawsoniana*
Southern white cedar	*Chamaecyparis thyoides*
Western juniper	*Juniperus utahensis* (Utah juniper) *Juniperus pachyphloea* (Alligator juniper) *Juniperus scopulorum* (Rocky Mountain red cedar) *Juniperus occidentalis* (western juniper)
Western red cedar	*Thuja plicata*
Cypress	
Red cypress (coast type)	*Taxodium distichum*
Yellow cypress (inland type)	*Taxodium distichum*
White cypress (inland type)	*Taxodium distichum*
Douglas Fir	
Douglas fir (coast type)	*Pseudotsuga taxifolia*
Red fir (intermountain type)	*Pseudotsuga taxifolia*
Red fir (Rocky Mountain type)	*Pseudotsuga taxifolia*
The True Firs	
Alpine fir	*Abies lasiocarpa*
Balsam fir	*Abies balsamea* and *Abies fraseri* (southern balsam fir)
Golden fir	*Abies magnifica*
Noble fir	*Abies nobilis*
Silver fir	*Abies amabilis*
White fir	*Abies concolor* and *Abies grandis* (lowland white fir)
Hemlocks	
Eastern hemlock	*Tsuga canadensis; Tsuga caroliniana* (Carolina hemlock)
Mountain hemlock	*Tsuga mertensiana*
West Coast hemlock	*Tsuga heterophylla*
Larch	
Western larch	*Larix occidentalis*

Standard Commercial Name	Botanical Name
Pines	
Arkansas soft pine	*Pinus echinata* and *taeda*
California white pine	*Pinus ponderosa* and *Pinus jeffreyi* (Jeffrey pine)
Idaho white pine	*Pinus monticola*
Jack pine	*Pinus banksiana*
Loblolly pine	*Pinus taeda*
Lodgepole pine	*Pinus contorta*
Longleaf pine	*Pinus palustris*
North Carolina pine	*Pinus taeda* and *echinata*, and *Pinus virginiana* (Virginia pine)
Northern white pine	*Pinus strobus*
Norway pine	*Pinus resinosa*
Pond pine	*Pinus rigida serotina*
Pondosa pine	*Pinus ponderosa*
Shortleaf pine	*Pinus echinata*
Slash pine	*Pinus caribaea*
Southern pine	*Pinus taeda, palustris, serotina, echinata*, and *caribaea*, and *Pinus rigida* (pitch pine), and *Pinus glabra* (spruce pine)
Sugar pine	*Pinus lambertiana*
Redwood	
Redwood	*Sequoia sempervirens*
Spruces	
Eastern spruce	*Picea mariana* (black spruce), *Picea rubra* (red spruce), and *Picea glauca* (white spruce)
Engelmann spruce	*Picea engelmanni* and *Picea parryana* (blue spruce)
Sitka spruce	*Picea sitchensis*
Tamarack	
Tamarack	*Larix laricina*
Yew	
Pacific yew	*Taxus brevifolia*

DEFINITIONS OF MAXIMUM DEFECTS AND BLEMISHES

Defects and blemishes enumerated in the rules for grading yard lumber of any species under American Lumber Standards are to be defined within the limits of the following definitions:

A *defect* is defined as any irregularity occurring in or on wood that may lower some of its strength, durability, or utility values.

A *blemish* is defined as anything not classified as a defect, marring the appearance of the wood.

The commonly recognized defects and blemishes occurring in various species of yard lumber are:

Bark pockets
Bird's-eye
Checks
Cross-breaks
Cross-grain
Decay
Gum spots or streaks
Holes
Imperfect manufacture
Knots
Pitch
Pitch pockets
Pitch seams
Pitch streaks
Pith
Pith flecks
Shake
Splits
Stain or discoloration
Wane
Warp

Bark Pockets.—A bark pocket is a patch of bark partially or wholly enclosed in the wood. In size it is classified the same as pitch pockets.

Bird's-eye.—Bird's-eye is a small central spot with the wood fibers arranged around it in the form of an ellipse, so as to give the appearance of an eye. Bird's-eye, unless unsound or hollow, shall not be considered a defect.

Checks.—A check is a lengthwise separation of the wood, which occurs usually across the rings of annual growth.

A *surface check* is a check occurring on the surface of the piece.

A *small surface check* is a perceptible opening not over 4 in. long.

A *medium surface check* is one not over $\frac{1}{32}$ in. wide and over 4 but not more than 10 in. long.

A *large surface check* is one over $\frac{1}{32}$ in. wide and over 10 in. long.

An *end check* is one occurring on an end of a piece.

A *through check* is one extending from one surface through the piece to the opposite surface or to an adjoining surface.

A *heart check* is one starting at the pith and extending toward but not to the surface of a piece.

Cross-breaks.—A cross-break is a separation of the wood cells across the grain, such as may be due to tension resulting from unequal shrinkage or mechanical stresses.

Cross-grain.—Cross-grained wood is that in which the cells or fibers do not run parallel with the axis or sides of a piece.

Slight cross-grain is a slope of the grain not over 1 in. in a length of 15 in.

Medium cross-grain is a slope of the grain over 1 in. in a length of 15 in. but not more than 1 in. in a length of 10 in.

Steep cross-grain is a slope of the grain over 1 in. in a length of 10 in.

Decay.—Decay is a disintegration of the wood substance due to the action of wood-destroying fungi. The words "dote" and "rot" mean the same as decay.

Incipient decay is the early stage of decay in which the disintegration has not proceeded far enough to soften or otherwise change the hardness of the wood perceptibly. It is usually accompanied by a slight discoloration or bleaching of the wood.

Firm red heart is a stage of incipient decay characterized by a reddish color produced in the heartwood, which does not unfit the wood for the majority of yard purposes.

Water soak (or *stain*) is a term applied to a generally water-soaked area in heartwood, which is usually interpreted as the incipient stage of certain wood rots.

Advanced (or *typical*) *decay* is the older stage of decay in which the disintegration is readily recognized because the wood has become punky, soft, and spongy, stringy, ring shaked, pitted, or crumbly. Decided discoloration or bleaching of the rotted wood is often apparent.

A *pocket rot* is typical decay which appears in the form of a hole, pocket, or area of soft rot, usually surrounded by apparently sound wood.

Gum Spots and Streal ...t or streak is an accumulation of gumlike substance occu... ...streak in a piece. It may occur in conjunction w... injury to the growing wood. In size, it is classified ...ets or pitch streaks.

Holes.—Holes in ... tially or entirely through the piece and be from ... ...s are permitted, the average of the maximum and ... measured at right angles to the direction of the b... asuring the size, unless otherwise stated.

A *pinwormhole* is one not over $\frac{1}{16}$ in. in diameter.

A *medium* ... $\frac{1}{16}$ but not more than $\frac{1}{4}$ in. in diameter.

A *large wormhole* is one over $\frac{1}{4}$ in. in diameter.

Imperfe ...erfect manufacture includes all defects or blemish... in manufacturing, such as chipped grain, loosened ... torn grain, skips in dressing, hit and miss, v... ...cut lumber, machine burn, machine gouge, mismatching, and insufficient tongue or groove.

Cl ...at a part of the surface is chipped or broken out i... ...below the line of cut. It should not be classed as t... ...ly found, shall not be considered a defect, unless it is present in excess of 25 per cent of the area.

...is that a small portion of the wood has become loosened but not displaced.

...oughened condition of the surface of dressed lumber ...mmerwood is raised above the softer springwood but ... it.

Torn grain means that a part of the wood is torn out in dressing and in depth is of four distinct characters: slight, medium, heavy, and deep.

Slight torn grain is not over 1/32 in. in depth.

Medium torn grain is over 1/32 but not more than 1/16 in. in depth.

Heavy torn grain is over 1/16 but not more than 1/8 in. in depth.

Deep torn grain is over 1/8 in. in depth.

A *skip* is an area on a piece that failed to surface.

A *slight skip* is one that failed to surface smoothly, whose area does not exceed the product of the width of the piece in inches multiplied by 6.

A *heavy skip* is one that the planer knife did not touch.

Hit and miss is a series of skipped spots with surfaced areas between or with skips the entire length when not over 1/16 in. in depth.

Variation in sawing is a deviation from the line of cut. Slight variation is not more than 1/16 in. in 1-in. material, 1/8 in. in 2-in., 3/16 in. in 3 to 7 in., and 1/4 in. in 8 in. and up.

Miscut lumber is that which has a greater variation in thickness or width at different places on the piece than specified for variation in sawing.

A *machine burn* is a darkening [illegible] ng of the wood due to overheating by machine knives.

A *machine gouge* is a g [illegible] e to the machine's cutting below the desired line of [illegible]

Mismatched material is [illegible] does not fit tightly at all points of contact between [illegible] which the surfaces of adjoining pieces are not in t[illegible]

Slight mismatch is a surface variation not over 1/64 in.

Medium mismatch is a sur[illegible] but not more than 1/32 in.

Heavy mismatch is a surface variation over 1/32 [illegible]

Knots.—A knot is a branch o[illegible] e tree which has been cut through in the process of l[illegible] Knots are classified according to size, form, qualit[illegible] The average of the maximum and minimum diamete[illegible] suring the size of knots, unless otherwise stated.

Size.—A *pin knot* is one not over 1/2 [illegible]

A *small knot* is one over 1/2 in. but [illegible] diameter.

A *medium knot* is one over 3/4 in. but n[illegible] diameter.

A *large knot* is one over 1 1/2 in. in dian[illegible]

Form.—A *round knot* is one oval or circ[illegible]

A *spike knot* is a branch or limb sawed i[illegible] n.

Quality.—A *sound knot* is solid across its fa[illegible] ounding wood, and shows no indications of decay. [illegible] from red to black.

An *unsound knot* is solid across its face but con[illegible] y.

A *decayed knot* is softer than the surrounding wood and contains advanced decay.

A *tight knot* is one so fixed by growth or position that it will firmly retain its place in the piece.

An *intergrown knot* is one whose rings of annual growth are completely intergrown with those of the surrounding wood.

A *watertight knot* is one whose rings of annual growth are completely intergrown with those of the surrounding wood on one surface of the piece, and which is sound on that surface.[1]

An *encased knot* is one whose rings of annual growth are not intergrown and homogeneous with those of the surrounding wood. The encasement may be partial or complete; or pitch or bark.

A *"not-firm" knot* is one which under ordinary conditions will hold its place in a dry board and yet under pressure can be started but not easily pushed out of place.

A *loose knot* is one not held firmly in place by growth or position and cannot be relied upon to remain in place in the board.

A *pith knot* is one which is sound with a pith hole not more than ¼ in. in diameter.

A *hollow knot* is an apparently sound knot with a relatively large hole in it.

Occurrence.—A *single knot* is one occurring by itself with the fibers of the wood in which it occurs deflected around it.

A *knot cluster* is the grouping of two or more knots together as a unit with the fibers of the wood deflected around the entire unit. A group of single knots is not a knot cluster.

Branch knots are two or more knots branching from a common center.

Pitch.—Pitch is a poorly defined accumulation of resin in the wood cells in a more or less irregular patch.

Light pitch is the lightly evident presence of pitch.

Medium pitch is a slightly more evident trace of pitch than is the light.

Heavy pitch is the very evident presence of pitch showing by its color and consistency.

Massed pitch is a clearly defined accumulation of solid pitch in a body by itself in a piece of lumber.

Pitch Pockets.—A pitch pocket is a well-defined opening between rings of annual growth, usually containing, or which has contained, more or less pitch, either solid or liquid. Bark also may be present in the pocket.

A *very small pitch pocket* is one not over ⅛ in. in width and not over 2 in. in length.

A *small pitch pocket* is one not over ⅛ in. in width and not over 4 in. in length or not over ¼ in. in width and not over 2 in. in length.

[1] Definitions for sound, tight, intergrown, or water-tight knots may be combined in one or more definitions.

A *medium pitch pocket* is one not over $\frac{1}{8}$ in. in width and not over 8 in. in length or not over $\frac{3}{8}$ in. in width and not over 4 in. in length.

A *large pitch pocket* is one whose width or length exceeds the maximum stated as permissible for a medium pitch pocket.

A *closed pitch pocket* is one that does not show an opening on both sides of the piece.

Pitch Seams.—A pitch seam is a shake or check which is filled with pitch.

Pitch Streaks.—A pitch streak is a well-defined accumulation of pitch in a more or less regular streak.

A *small pitch streak* is one not over one-twelfth the width by one-sixth the length of the surface on which it occurs.

A *medium pitch streak* is one over one-twelfth but not more than one-sixth the width by over one-sixth but not more than one-third the length of the surface on which it occurs.

A *large pitch streak* is over one-sixth the width by one-third the length of the surface on which it occurs.

Pith.—Pith is the small, soft core occurring in the structural center of a log. The wood immediately surrounding the pith often contains small checks, shakes, or numerous pin knots and is discolored; any such combination of defects and blemishes is known as *heart center.*

Pith Flecks.—A pith fleck is a narrow streak resembling pith, usually brownish, up to several inches in length on the surface of a piece resulting from the burrowing of larvæ in the growing tissue of the tree.

Shake.—A shake is a lengthwise separation of the wood, which occurs usually between and parallel to the rings of annual growth.

A *fine shake* is one with a barely perceptible opening.

A *slight shake* is one with more than a perceptible opening but not over $\frac{1}{32}$ in. in width.

A *medium shake* is one with an opening over $\frac{1}{32}$ but not more than $\frac{1}{8}$ in. wide.

An *open shake* is one with an opening over $\frac{1}{8}$ in. wide.

A *through shake* is one extending from one surface through the piece to the opposite surface or to an adjoining surface.

Splits.—A split is a lengthwise separation of the wood, due to the tearing apart of the wood cells.

A *short split* is one whose length does not exceed either the width of a piece or one-sixth its length.

A *medium split* is one whose length exceeds the width of a piece but does not exceed one-sixth its length.

A *long split* is one whose length exceeds one-sixth the length of a piece.

Stain (or Discoloration).—Stain is a discoloration, occurring on or in lumber, of any color other than the natural color of the piece on which it appears. It is classified as light, medium, and heavy.

Light stain is a slight difference in color which will not materially impair the appearance of the piece if given a natural finish.

Medium stain is a pronounced difference in color which, although it does not obscure the grain of the wood, would customarily be objectionable in a natural but not in a painted finish.

Heavy stain is a difference in color so pronounced as practically to obscure the grain of the wood.

Wane.—Wane is bark, or the lack of wood or bark, from any cause, on the edge or corner of a piece.

Slight wane is not over ¼ in. wide on the surface on which it appears, for one-sixth the length and one-fourth the thickness of the piece.

Medium wane is over ¼ but not more than ½ in. wide on the surface on which it appears, for one-sixth the length and one-fourth the thickness of the piece.

Large wane is over ½ in. wide on the surface on which it appears and/or over one-sixth the length and one-fourth the thickness of the piece.

Warp.—Warp is any variation from a true or plane surface. It includes bow, crook, cup, or any combination thereof.

Bow is a deviation flatwise from a straight line drawn from end to end of a piece and is measured at the point of greatest distance from the straight line.

Crook is a deviation edgewise from a straight line drawn from end to end of a piece and is measured at the point of greatest distance from the straight line. It is known as *slight*, *small*, *medium*, and *large*.

Based on a piece 4 in. wide and 16 ft. long, the distances for the different degrees of crook shall be: for slight crook, a maximum of 1 in.; small crook, 1½ in.; medium crook, 3 in.; and large crook, over 3 in. For wider pieces it shall be ⅛ in. less for each additional 2 in. in width. Shorter or longer pieces may have the same curvature.

Cup is a curve in a piece across the grain or width of a piece. It is measured at the point of greatest deviation from a straight line drawn from edge to edge of a piece. It is known as *slight*, *medium*, and *deep*.

Based on a piece 12 in. wide, the distances for the different degrees of cup shall be: for slight cup, a maximum of ¼ in.; medium cup, ⅜ in.; and deep cup, ½ in. Narrower or wider pieces may have the same curvature.

STANDARD LUMBER ABBREVIATIONS

The following standard lumber abbreviations when used in contracts and other documents arising in the transactions of purchase and sale of American standard lumber shall be construed as hereinafter provided:

AD.....	Air dried.
a. l.....	All lengths.
av.....	Average.
av. w.....	Average width.
av. l.....	Average length.
a.w.....	All widths.
B1S.....	Beaded one side.
B2S.....	Beaded two sides.

BBS..... Box bark strips.
bd..... Board.
bd. ft..... Board foot; that is, an area of 1 sq. ft. by 1 in. thick.
bdl..... Bundle.
bdl. bk. s..... Bundled bark strips.
Bev..... Beveled.
B/L..... Bill of lading.
b.m..... Board (foot) measure.
Btr..... Better.
c.&.f..... (*Named port.*) *Cost and freight to named port.* Term used when the seller is ready to go further than the delivery of his goods upon a vessel and is willing to pay transportation to another port.
c.i.f..... (*Named port.*) *Cost, insurance, and freight to a named port.* Term used when the seller desires to quote a price covering the cost of the goods, the marine insurance on the goods, and all transportation charges to the point of delivery.
c.i.f.e..... (*Named port.*) *Cost, insurance, freight, and exchange to a named port.* This is the same as c.i.f. with the additional provision that the seller guarantees the buyer against loss due to a decline in the rate of exchange.
Clg..... Ceiling.
Clr..... Clear.
CM..... Center matched; that is, the tongue and groove joints are worked along the center of the edges of the piece.
Com..... Common.
Coop..... Cooperage (stock).
Csg..... Casing.
Ctg..... Crating.
cu. ft..... Cubic foot.
Cust..... Custom (sawed).
D&CM..... Dressed (one or two sides) and center matched.
D&H..... Dressed and headed; that is, dressed one or two sides and worked to tongue and groove joints on both the edge and the ends.
D&M..... Dressed and matched; that is, dressed on one or two sides and tongued and grooved on the edges. The match may be center or standard.
D&SM..... Dressed (one or two sides) and standard matched.
D2S&CM.... Dressed two sides and center matched.
D2S&M..... Dressed two sides and (center or standard) matched.
D2S&SM..... Dressed two sides and standard matched.
Dim..... Dimension.
D.S..... Drop siding.
E..... Edge.
E&CB1S..... Edge and center bead one side; surfaced one or two sides and with a longitudinal edge and center bead on a surfaced face.
E&CB2S..... Edge and center bead two sides, all four sides surfaced and with a longitudinal edge and center bead on the two faces.
ECM..... Ends center matched.
E&CV1S..... Edge and center V one side; surfaced one or two sides and with a longitudinal edge and center V-shaped groove on a surfaced face.
E&CV2S..... Edge and center V two sides; all four sides surfaced and with a longitudinal edge and cen-

ter V-shaped groove on each of the two faces.

E.G..... Edge grain.

EM..... End matched—either center or standard.

ESM..... End standard matched.

exp..... Export (lumber or timber).

FAS..... First and seconds—a combined grade of the two upper grades of hardwoods.

f.a.s. vessel... (*Named port.*) *Free alongside of vessel at a named port.* Term used when the seller desires to quote a price covering delivery of the goods alongside of a vessel and within reach of its loading tackle.

f. bk..... Flat back.

fcty..... Factory (lumber).

F.G..... Flat grain.

Flg..... Flooring.

f.o.b..... (*Named shipment point.*) *Free on board at a named shipping point.* Term used when the price quoted applies only to an inland shipping point and the seller merely undertakes to load the goods on or in cars or lighters furnished by the railroad company serving the industry, or most conveniently located to the industry, without other designation as to routing.

f.o.b..... (*Named point.*) *Freight prepaid to (named point). Free on board at a named point and freight prepaid to a named point.* Term used when the seller quotes a price including transportation charges to a given point without assuming responsibility for the goods after obtaining a clean bill of lading at point of origin.

f.o.b..... (*Named point.*) *Freight allowed to (named point). Free on board at a named point and freight allowed to a named point.* Term used where the seller wishes to quote a price from which the buyer may deduct the cost of transportation to the point of destination, without the seller's assuming responsibility for the goods after obtaining a clean bill of lading at the point of origin.

f.o.b. cars..... (*Named destination point.*) *Free on board cars at a named destination point.* Term used when the seller desires to quote a price covering the transportation of the goods to a given point, assuming responsibility for loss and / or damage up to that point.

f.o.b. cars..... (*Named point.*) *Free on board cars at a named point less carload lots.* Term used when the goods on which a price is quoted to a given point constitutes less than a carload lot.

f.o.b..... (*Named port.*) *Lighterage free. Free on board at a named port with lighterage free.* Term used when seller desires to quote a price which will include the expense of transportation of the goods by

rail to the seaboard, including lighterage.

f.o.b. vessel... (*Named port.*) *Free on board vessel at a named port.* Term used when the seller desires to quote a price covering all expenses up to and including delivery of the goods upon a vessel at a named port.

f.o.k..... Free of knots.

f.o.w..... First open water.

Frm..... Framing.

ft..... Feet or foot. Also one accent (′). See symbols.

ft. b.m..... Feet board measure.

ft. s.m..... Feet surface measure.

Furn..... Furniture (stock).

G.R..... Grooved roofing.

H.bk..... Hollow back.

Hdl..... Handle (stock).

hdwd..... Hardwood.

Hrt..... Heart.

Hrtwd..... Heartwood.

1s&2s..... Ones and twos—a combined grade of the hardwood grades of first and seconds.

Impl..... Implement (stock).

in..... Inch or inches. Also two accents (″). See symbols.

KD..... Kiln dried.

k.d..... Knocked down.

lbr..... Lumber.

l.c.l..... Less than carload lots.

lgth..... Length.

lgr..... Longer.

lin. ft..... Lineal foot; that is, 12 in.

Lng..... Lining.

LR..... Log run.

LR,MCO..... Log run, mill culls out.

Lth..... Lath.

M..... Thousand.

M.b.m..... Thousand (feet) board measure.

MCO..... Mill culls out.

Merch..... Merchantable.

m.l..... Mixed lengths.

Mldg..... Molding.

MR..... Mill run.

M.s.m..... Thousand (feet) surface measure.

m.w..... Mixed widths.

No..... Number.

Ord..... Order.

P..... Planed.

Pat..... Pattern.

Pky..... Pecky.

Pln..... Plain, as plain sawed.

Pn..... Partition.

Prod..... Production.

Qtd..... Quartered. When referring to hardwoods.

rdm..... Random.

res..... Resawed.

Rfg..... Roofing.

Rfrs..... roofers.

rip..... ripped.

r.l..... Random lengths.

rnd..... Round.

R. Sdg..... Rustic siding.

r.w..... Random widths.

S&E..... Surfaced one side and one edge.

S1E..... Surfaced one edge.

S2E..... Surfaced two edges.

S1S..... Surfaced one side.

S2S..... Surfaced two sides.

S1S1E..... Surfaced one side and one edge.

S2S1E..... Surfaced two sides and one edge.

S1S2E..... Surfaced one side and two edges.

S4S..... Surfaced four sides.

S4SCS..... Surfaced four sides with a calking seam on each edge.

S&CM..... Surfaced (one or two sides) and center matched.

S&M..... Surfaced and matched; that is, surfaced one or two sides and tongued and grooved on the edges. The match may be center or standard.

S&SM..... Surfaced (one or two sides) and standard matched.

S2S&CM..... Surfaced two sides and center matched.
S2S&M..... Surfaced two sides and (center or standard) matched.
S2S&SM..... Surfaced two sides and standard matched.
Sap..... Sapwood.
SB..... Standard bead.
Sd..... Seasoned.
Sdg..... Siding.
Sel..... Select.
S.E.Sdg..... Square edge siding.
s.f..... Surface foot; that is, an area of 1 sq. ft.
Sftwd..... Softwood.
Sh.D..... Shipping dry.
Ship..... Shipment or shipments.
Shlp..... Shiplap.
s.m..... Surface measure.
SM..... Standard matched.
smkd..... Smoked (dried).
smk. stnd.... Smoke stained.
s.n.d..... Sap no defect.
snd..... Sound.
sq..... Square.
Sq. E&S..... Square edged and sound.
sqrs..... Squares.
Std..... Standard.
stnd..... Stained.
stk..... Stock.
Stp..... Stepping.
S.W..... Sound wormy.
Symbols:
"..... inch or inches, as 12".
'..... foot or feet, as 12'.
×..... by, as a 6 × 8 timber.
4/4, 5/4, 6/4, 8/4, etc. = 1 in., 1¼ in., 1½ in., 2 in., etc., when referring to the size of lumber.
T&G..... Tongued and grooved.
TB&S..... Top, bottom, and sides.
Tbrs..... Timbers.
V1S..... V one side; that is, a longitudinal V-shaped groove on one face of a piece of lumber.
V2S..... V two sides; that is, a longitudinal V-shaped groove on two faces of a piece of lumber.
V.G..... Vertical grain.
w.a.l..... Wider, all lengths.
Wth..... Width.
wdr..... Wider.
Wgn..... Wagon (stock).
wt..... Weight.

AMERICAN STANDARDS FOR SOFTWOOD YARD LUMBER

1. Yard Lumber.—The term *yard lumber* as here used means lumber that is manufactured and classified into those sizes, shapes, and qualities required for ordinary construction and general-purpose uses.

2. Other Lumber and Timber Classifications.—Heavy timbers for structural purposes, softwood factory and shop lumber, hardwood factory lumber, and other special-use materials are not considered yard stock.

Grade Standards

3. Grades.—On the basis of quality, yard lumber is divided into two main divisions: (*a*) select lumber, and (*b*) common lumber.

These are again divided into two classes: select lumber into (1) that suitable for natural finishes, and (2) that suitable for paint finishes; common lumber into (1) that which can be used without waste, and (2) that which permits some waste.

Each of these four classes is further divided into quality classes or grades.

Select Lumber

4. Select Lumber.—Lumber which is generally clear, containing defects limited both as to size and number and which is smoothly finished and suitable for use as a whole for finishing purposes or other uses in which large clear pieces are required, shall be considered select lumber.

5. Two classes shall be recognized. The first shall be suitable for natural finishes. The second class permits similar defects and, in addition, blemishes of somewhat greater extent than those of the first class but of a type which can be covered by paint. Grade names are A, B, C, and D.

Common Lumber

6. Common Lumber.—Lumber containing numerous defects and blemishes which preclude it from use for finishing purposes, but which is suitable for general utility and construction purposes, shall be considered common lumber.

7. Two general classes shall be recognized. The first shall be suitable for use as a whole for purposes in which surface covering or strength is required. Defects and blemishes permitted in this class must be sound. The second class permits very coarse defects which may cause waste in the use of the piece.

Board grade names:

No. 1 common.
No. 2 common.
No. 3 common.
No. 4 common.
No. 5 common.

Dimension grade names:

No. 1 common.
No. 2 common.
No. 3 common.

8. BASIC GRADE CLASSIFICATION FOR YARD LUMBER

- Total products of a typical log arranged in series according to quality as determined by appearance
  - Select: Lumber of good appearance and finishing qualities
    - Suitable for natural finishes
      - Grade A: Practically free from defects
      - Grade B: Allows a few small defects or blemishes
    - Suitable for paint finishes
      - Grade C: Allows a limited number of small defects or blemishes which can be covered with paint
      - Grade D: Allows any number of defects or blemishes which do not detract from a finish appearance, especially when painted
  - Common: Lumber containing defects or blemishes which detract from a finish appearance but which is suitable for general utility and construction purposes
    - Lumber suitable for use without waste
      - No. 1 Common: Sound and tight knotted stock. Size of defects and blemishes limited. May be considered water-tight lumber
      - No. 2 Common: Allows large and coarse defects. May be considered grain-tight lumber
    - Lumber permitting waste
      - No. 3 Common: Allows larger and coarser defects than No. 2 and occasional knot holes
      - No. 4 Common: Low-quality lumber admitting the coarsest defects such as rot and holes
      - No. 5 Common: Must hold together under ordinary handling

9. Reference to Regional Associations.—With the above as a basis, the various regional lumber manufacturers' associations have published grading rules in detail for their products, and reference should be made to these rules in interpreting the practical application of these divisions of lumber into quality classes.

10. Contracts Should Be Based on Regional Rules.—In grades, and in definitions of defects, some of the provisions vary slightly from the American Lumber Standards, and the particular rules under which shipment is to be made should be considered in making contracts.

General Provisions

11. Rules of Inspection.—No arbitrary rules for the inspection of lumber can be maintained with satisfaction. The variations from any given rule are numerous and suggested by practical common sense, so nothing more definite than the general features of different grades should be attempted by rules of inspection.

12. Variation in Grading and Inspection.—The grading of lumber cannot be considered an exact science, because it is based on a visual inspection of each piece and on the judgment of the grader. The provisions of these specifications, however, are sufficiently explicit to establish 5 per cent below grade as a reasonable variation between graders.

13. Grading of Yard Lumber.—All yard lumber is graded with reference to its suitability for general use as yard lumber. With this in view, each piece is considered and its grade determined by its general character, including the location and sum of all of its defects and blemishes. Material not conforming to standard sizes or grades shown herein and that intended for special uses shall be covered by special contract and inspection.

14. Better Face.—Except in dimension, the grade of yard lumber, rough or surfaced two sides, shall be determined from the better or face side of the piece, and lumber which is surfaced one side only shall be graded from the surfaced side.

15. Poorest Piece.—The rules for yard lumber prescribe the number and extent of defects and blemishes in the poorest piece admissible in each grade. A grade should be representative, however, and not made up of only low line pieces.

16. Area of Piece.—The number of defects and blemishes permitted varies as the area of the piece to be graded increases or diminishes in respect to the basic size or area specified, but the size of the defects must not exceed that allowed by the grading rules.

17. Combinations of Defects.—When defects or blemishes or combinations thereof, not described in these grading rules, are encountered, they will be considered as equivalent to known defects according to their damaging effect upon the piece in the grade under consideration.

18. Equivalent Means Equal.—Equivalent means equal, and in construing and applying these rules, the defects and blemishes allowed, whether specified or not, are understood to be equivalent in damaging effect to those mentioned applying to the stock under consideration.

19. Imperfections in Rough Stock.—Imperfections in rough stock which can be removed in dressing to standard size shall not be considered in determining the grade under these rules.

20. Defects Admissible in Rough Stock.—Defects and blemishes admissible in rough stock shall be the same as those applying to dressed

stock of like kind and grade, and, in addition, such other defects and blemishes as will disappear in dressing such stock to standard sizes shall be allowed.

21. Edge Grain.—Material shall be considered edge grain (vertical grain) when the rings (so-called *grain*) form an angle of 45 deg. or more with the surface of the piece. When the angle becomes less than 45 deg. at any point, the material shall be known as *flat* (*slash*) *grain*.

22. Mixed Grades.—Mixed grades other than the two highest recognized grades for each species, not specifying the proportion of each grade, are not American Lumber Standard grades.

Lumber Seasoning

23. Specifications dealing with lumber seasoning and moisture content shall be developed by each regional manufacturers' association in accordance with its own conditions and the requirements of the users of its products. Such specifications adopted from time to time by any regional association shall be filed with the Central Committee on Lumber Standards for approval.

Yard and Industrial Size Standards

Basis of Measurement of Sizes

24. The dressed dimensions, specified in paragraphs 26, 27, 28, 29, and 42, and the rough sizes specified in paragraphs 30 to 32, inclusive, shall apply to lumber in the condition of seasoning as sold and shipped.

Dressed Sizes

25. The terms *standard yard board* and *standard industrial board, standard yard dimension* and *standard industrial dimension* shall be the designations for 1-in. boards and 2-in. dimension, respectively.

26. The thickness for the standard yard board shall be $^{25}/_{32}$ in. S1S or S2S; for the standard industrial board, $^{26}/_{32}$ in., S1S, or S2S.

27. The thickness for standard yard dimension not more than 12 in. wide shall be $1^{5}/_{8}$ in., S1S or S2S; for standard industrial dimension, $1^{3}/_{4}$ in., S1S or S2S.

28. The finished widths of finish S1E or S2E shall be $^{3}/_{8}$ in. off on lumber of standard width of 3 in.; the finished widths of finish S1E or S2E (based on kiln-dried lumber) shall be $^{1}/_{2}$ in. off on lumber of standard widths of 4 to 7 in., inclusive, and $^{3}/_{4}$ in. off on lumber of standard widths of 8 to 12 in., inclusive; and the finished widths of boards and dimension S1E or S2E shall be $^{3}/_{8}$ in. off on lumber of standard widths less than 8 in. and $^{1}/_{2}$ in. off on lumber of standard widths of 8 to 12 in.

29. The thickness and width of finished lumber, S1S or S2S and/or S1E or S2E, shall be in accordance with the following tables:

FINISH, COMMON BOARDS AND STRIPS, DIMENSION AND HEAVY JOIST

(The thicknesses apply to all widths and the widths to all thicknesses)

Product	Size, board measure		Dressed dimensions		
	Thickness, inches	Width, inches	Standard thickness, yard, inches	Standard thickness, industrial, inches	Standard width, inches
Finish	...	3	5/16	.....	2 5/8
	...	4	7/16	.....	3 1/2
	...	5	9/16	.....	4 1/2
	...	6	11/16	.....	5 1/2
	1	7	25/32	26/32	6 1/2
	1 1/4	8	1 1/16	.....	7 1/4
	1 1/2	9	1 5/16	.....	8 1/4
	1 3/4	10	1 7/16	.....	9 1/4
	2	11	1 5/8	1 5/8	10 1/4
	2 1/2	12	2 1/8	.....	11 1/4
	3	..	2 5/8	.....	.....
Common boards and strips	1	3	25/32	26/32	2 5/8
	1 1/4	4	1 1/16	.....	3 5/8
	1 1/2	5	1 5/16	.....	4 5/8
	...	6	.....	.....	5 5/8
	...	7	.....	.....	6 5/8
	...	8	.....	.....	7 1/2
	...	9	.....	.....	8 1/2
	...	10	.....	.....	9 1/2
	...	11	.....	.....	10 1/2
	...	12	.....	.....	11 1/2
Dimension and heavy joist	2	2	1 5/8	1 5/8	1 5/8
	2 1/2	4	2 1/8	.....	3 5/8
	3	6	2 5/8	.....	5 5/8
	4	8	3 5/8	.....	7 1/2
	...	10	.....	.....	9 1/2
	...	12	.....	.....	11 1/2

[1] Based on kiln-dried lumber.

SIDING, FLOORING, CEILING, PARTITION, SHIPLAP, AND DRESSED AND MATCHED

(The thicknesses apply to all widths and the widths to all thicknesses, except as modified by the note below[1])

Product	Size, board measure		Dressed dimensions	
	Thickness, inches	Width, inches	Standard thickness, inches	Standard face width, inches
Bevel siding	...	4	7/16 (minimum) × 3/16	3 1/2
	...	5	10/16 × 3/16	4 1/2
	...	6	.....	5 1/2
Wide bevelled siding	...	8	7/16 (minimum) × 3/16	7 1/4
	...	10	9/16 × 3/16	9 1/4
	...	12	11/16 × 3/16	11 1/4
Rustic and drop siding (ship-lapped)	...	4	9/16	3 1/8
	...	5	3/4	4 1/8
	...	6	.....	5 1/16
	...	8	.....	6 7/8
Rustic and drop siding (dressed and matched)	...	4	9/16	3 1/4
	...	5	3/4	4 1/4
	...	6	.....	5 3/16
	...	8	.....	7
Flooring	...	2	5/16	1 1/2
	...	3	7/16	2 3/8
	...	4	9/16	3 1/4
	1	5	25/32	4 1/4
	1 1/4	6	1 1/16	5 3/16
	1 1/2	...	1 5/16	
Ceiling	...	3	5/16	2 3/8
	...	4	7/16	3 1/4
	...	5	9/16	4 1/4
	...	6	11/16	5 3/16
Partition	...	3	3/4	2 3/8
	...	4	.....	3 1/4
	...	5	.....	4 1/4
	...	6	.....	5 3/16
Shiplap	1	4	25/32	3 1/8
	...	6	.....	5 1/8
	...	8	.....	7 1/8
	...	10	.....	9 1/8
	...	12	.....	11 1/8
Dressed and matched	1	4	25/32	3 1/4
	1 1/4	6	1 1/16	5 1/4
	1 1/2	8	1 5/16	7 1/4
	...	10	.....	9 1/4
	...	12	.....	11 1/4

[1] In tongued-and-grooved flooring and in tongued-and-grooved and ship-lapped ceiling 5/16, 7/16, and 9/16 in. thick, board measure, the tongue or lap shall be 3/16 in. wide, with the over-all widths 3/16 in. wider than the face widths shown above. In all other patterned material, 11/16, 3/4, 1, 1 1/4, and 1 1/2 in. thick, board measure, the tongue shall be 1/4 in. wide in tongued-and-grooved lumber, and the lap 3/8 in. wide in ship-lapped lumber, with the over-all widths 1/4 and 3/8 in. wider, respectively, than the face widths shown above.

FACTORY FLOORING, HEAVY ROOFING, DECKING, AND SHEET PILING

(The thicknesses apply to all widths and the widths to all thicknesses)

Size, board measure		Dressed dimensions			
Thickness, inches	Width, inches	Standard thickness, inches	Standard face width[1]		
			D & M, inches	Ship-lapped, inches	Grooved for splines, inches
2	4	1⅝	3⅛	3	3½
2½	6	2⅛	5⅛	5	5½
3	8	2⅝	7⅛	7	7½
4	10	3⅝	9⅛	9	9½
...	12	...	11⅛	11	11½

[1] In patterned material 2 in. and thicker, board measure, the tongue shall be ⅜ in. wide in tongued-and-grooved lumber and the lap ½ in. wide in ship-lapped lumber, with the over-all widths ⅜ and ½ in. wider, respectively, than the face widths shown above.

Rough-dry Sizes

30. Thickness One-inch Board.—The standard rough-dry thickness of the standard yard board shall be not less than $^{29}/_{32}$ in. with an allowance of 20 per cent of the shipment, which may be not less than $^{28}/_{32}$ in., and the standard rough-dry thickness of the standard industrial board shall be not less than $^{30}/_{32}$ in. with an allowance of 10 per cent of the shipment, which may be not less than $^{29}/_{32}$ in.

31. Thick Boards.—The standard rough-dry thickness of finish, common boards, and dimension of standard sizes of 1¼ in. and thicker, board measure, shall be not less than ⅛ in. thicker than the corresponding standard finished dry thickness, with an allowance of 20 per cent of the shipment, which may be not less than $^{3}/_{32}$ in. thicker than the corresponding standard finished dry thickness.

32. Widths.—The standard rough-dry width of finish of 3-in. width, board measure, shall be not more than ¼ in. less than the nominal width; the standard rough kiln dried widths of finish, of widths 4 to 7 in., inclusive, board measure, shall be not more than ⅜ in. less than the nominal widths, and widths 8 to 12 in., inclusive, board measure, shall be not more than ⅝ in. less than the nominal widths; and the standard rough-dry widths of common boards and dimension, 7 in. and narrower board measure, shall be not more than ¼ in. less than the nominal widths, and the widths 8 to 12 in., board measure, shall be not more than ⅜ in. less than the nominal widths.

Lengths

33. Lengths.—With the exception of the following enumerated odd lengths, which shall be standard, odd lengths in yard lumber and in structural material shall not be considered in American Lumber Standards:

2″ × 4″, 6″ and 8″—9 and 11 ft.
2″ × 8″ and 10″—13 ft.
2″ × 10″—15 ft.
8″ × 8″, 10″ × 10″, 10″ × 12″, 12″ × 12″, 14″ × 14″, 16″ × 16″, 18″ × 18″—11 and 13 ft.
6″ × 16″, 6″ × 18″, 8″ × 16″, 8″ × 18″—15 and 17 ft.

The marketing practice covering lengths of yard lumber shall permit the buyer to secure specified lengths and/or specified assortments of lengths.

Workings

34. Flooring.—The standard workings of flooring, ceiling, partition, surfaced two sides and center-matched, drop siding, heavy flooring, grooved for splines, shiplap, and Byrkit lath, as shown in Revised Simplified Practice Recommendation No. 16 of the U. S. Department of Commerce, shall be considered standard. All other workings shall be considered special.

35. End Trimming.—Unless otherwise stated in the contract of purchase, yard lumber shall be double end-trimmed with a tolerance of not to exceed 3 in. in excess of nominal length.

Moldings

36. Wood Moldings.—The standard designs and universal sizes of wood moldings (known as the 7,000 *series of American Standard moldings*) shall be considered standard. All other designs and sizes shall be considered special.

DESCRIPTION, MEASUREMENT, AND TALLY

37. Standard Sizes.—The thicknesses and widths of yard lumber as specified in section 29 shall be considered standard. All other sizes shall be considered special.

38. Description.—Lumber of standard size shall be described by those standard dimensions.

39. Tally.—Lumber of standard size shall be tallied board measure. On lumber of standard thickness less than 1 in. (board measure), the board-foot measurement shall be based on the surface dimensions.

40. Tally of Dressed Lumber.—The board measurement of dressed lumber of standard size shall be based upon the corresponding nominal dimensions rough green lumber.

41. Special Size.—Lumber finished to special size shall be counted (tallied) as of the standard rough size necessarily used in its manufacture.

42. Measurement.—The measurement and description of the dimensions of lumber shall be as follows:

Thickness of Lumber Measured and Described as	Minimum Thickness, S1S or S2S, Inches
1 in., board measure, to be not less than	25/32
1¼ in., board measure, to be not less than	1 1/32
1½ in., board measure, to be not less than	1 9/32
1¾ in., board measure, to be not less than	1 13/16
2 in., board measure, to be not less than	1 5/8
2½ in., board measure, to be not less than	2 1/8
3 in., board measure, to be not less than	2 5/8
3½ in., board measure, to be not less than	3 1/8
4 in., board measure, to be not less than	3 5/8

Widths of finish, measured and described as 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12 in., board measure, to be, respectively, not less than 2⅝, S1E or S2E, in the condition of seasoning as sold and shipped, and 3½, 4½, 5½, 6½, 7¼, 8¼, 9¼, 10¼, and 11¼ in., S1E or S2E, based on kiln-dried lumber; widths of boards and dimension, measured and described as 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12 in., board measure, to be, respectively, not less than 1⅝, 2⅝, 3⅝, 4⅝, 5⅝, 6⅝, 7½, 8½, 9½, 10½, and 11½ in., S1E or S2E, in the condition of seasoning as sold and shipped.

The description of thickness of dressed stock less than 1 in. thick, board measure, S1S or S2S, to be its actual thickness in the condition of seasoning as sold and shipped.

Note.—It is to be understood that the standard dimensions of rough lumber are in excess of the dimensions of finished lumber of the corresponding size, board measure, by the amount necessary to permit of surfacing either one side or two side and/or one edge or two edges.

43. Stock Sizes.—Material shipped on stock sizes shall be tallied by the number of pieces of each size and length in the shipment.

44. Piece Tally.—In shipments measured on board measure a piece tally in board feet shall be made.

45. Fractions of Board Foot.—In material measured with a board rule on actual widths, pieces measuring to the even ½ ft. shall be alternately counted as of the next higher and lower foot count; fractions below the ½ ft. shall be dropped; fractions above the ½ ft. shall be counted as of the next higher foot.

SHIPPING PROVISIONS

46. Invoice Dimensions of Non-standard Lumber.—The actual thickness and width of lumber shipped when not of standard size shall be indicated on invoice.

47. Maintenance of Standard Sizes.—In order to encourage the maintenance of standard sizes, as agreed to, lumber manufactured and sold as standard, if grade marked, shall be marked by an appropriate brand or insignia to indicate that it is of standard size.

48. Uneven Sawing.—In shipments of rough finish and boards, pieces ½ in. or more above the count thickness, such as may be produced by uneven sawing, may, at the option of the buyer, be rejected or accepted as of the next lower grade.

49. Average Length.—The average length of a shipment of lumber shall be computed by dividing the total length in feet by the total number of pieces in a shipment.

50. Bundling.—Each length of bundle stock shall be bundled separately.

Grade Marking

51. Principle Approved.—The principle of grade marking of lumber is approved.

52. Grade-marking Methods.—On lumber when grade marked:

a. The grade to be marked on lumber of grades equivalent to No. 4 common and better grades, and on lower grades the grade mark to be optional.

b. If marked at all, *all* pieces of a given grade to be grade marked (except that unavoidable mechanical skips are, of course, allowed).

c. An easily branded mark or insignia, copyrighted and nationally uniform, to be used in connection with the grade mark and be available to identify shipments from all mills of lumber manufactured in accordance with American Lumber Standards.

d. An appropriate mark symbolizing American Lumber Standards to be copyrighted and its use to be available to those mills which shall have agreed to maintain the agreed standards of size and grade and to submit their lumber product upon complaint to official association inspection.

AMERICAN STANDARDS FOR SHINGLES

1. Grades.—The basic grades of shingles shall be *A*, *B*, *C*, and *D*. The grade name shall be clearly marked on each and every bundle of wood shingles.

2. Sizes.—Sixteen-inch 6/2 shingles and 18-in. 5/2 shingles shall be eliminated.

3. Dimension shingles shall be sold full net count, no dimension shingle to be less than $\frac{1}{8}$ in. scant of the specified width when dried.

Shipping Provisions

4. Dryness and Shipping Weight.—The kiln-dried weight of shingles shall be not more than 10 per cent under the present association shipping weights.

5. Openings.—The openings shall not exceed an average of 1 in. to the course in random-width shingles.

Standard Grades of Red-cedar Shingles

Grade A.—To be strictly clear, edge grain, and free from sap. Random widths.

6. 24″ Shingles 4/2″.—No shingle to be narrower than 4 in. If packed by M (see Standard Lumber Abbreviations, p. 58), must count 14/14 courses to bunch, 9 bunches to M. If packed by the square, must count 14/14 courses to bunch, 4 bunches to square, 7½ in. exposure, and 3 bunches to square, 10 in. exposure. Bunches must measure 7 in. across butts when green, 6¾ in. when dry.

7. 18″ Shingles 5/2¼″.—No shingle to be narrower than 3 in. If packed by M must count 20/20 courses to bunch, 5 bunches to M. Bunches must measure 9 in. across butts when green, 8¾ in. when dry. If packed by the square must count 18/18 courses to bunch, 4 bunches to square. Bunches must measure 8⅛ in. across butts when green, 7⅞ in. when dry.

8. 16″ Shingles 5/2″.—No shingle to be narrower than 3 in. If packed by M must count 25/25 courses to bunch, 4 bunches to M. Bunches must measure 10 in. across butts when green, 9¾ in. when dry. If packed by the square must count 20/20 courses to bunch, 4 bunches to square, or 5 to M. Bunches must measure 8 in. across butts when green, 7¾ inches when dry.

Grade B.—To be strictly clear, mixed edge grain and flat grain, ½ in. sap, measured 5 in. from butt, on one edge only permitted.

9. 24″ Shingles 4/2″.—None.

10. 18″ Shingles 5/2¼″.—No shingle to be narrower than 3 in. If packed by M must count 20/20 courses to bunch, 5 bunches to M. Bunches must measure 9 in. across butts when green, 8¾ in. when dry. If packed by the square must count 18/18 courses to bunch, 4 bunches to square. Bunches must measure 8⅛ in. across butts when green, 7⅞ in. when dry.

11. 16″ Shingles 5/2″.—No shingle to be narrower than 3 in. If packed by M, must count 25/25 courses to bunch, 4 bunches to M. Bunches must measure 10 in. across butts when green, 9¾ in. when dry. If packed by square, must count 20/20 courses to bunch, 4 bunches to square, or 5 to M. Bunches must measure 8 in. across butts when green, 7¾ in. when dry.

Grade C.—Ten-inch clear butts and better for 16 and 18-in. shingles and 16-in. clear butts and better for 24-in. shingles not permitted in higher grades. Sap permitted.

12. 24″ Shingles 4/2″.—No shingle to be narrower than 3 in. If packed by M must count 14/14 courses to bunch, 9 bunches to M. If packed by square, must count 14/14 courses to bunch, 4 bunches to square, 7½ in. exposure, and 3 bunches to square, 10-in. exposure. Bunches must measure 6¾ in. across butts when green, 6½ in. when dry.

13. 18″ Shingles 5/2¼″.—No shingle to be narrower than 2½ in. If packed by M, must count 20/20 courses to bunch, 5 bunches to M.

Bunches must measure 8¾ in. across butts when green, 8½ in. when dry. If packed by the square must count 18/18 courses to bunch, 4 bunches to square. Bunches must measure 7⅞ in. across butts when green, 7⅝ in. when dry.

14. 16″ Shingles 5/2″.—No shingle to be narrower than 2½ in. If packed by M, must count 25/25 courses to bunch, 4 bunches to M. Bunches must measure 9¾ in. across butts when green, 9½ in. when dry. If packed by the square must count 20/20 courses to bunch, 4 bunches to square, or 5 to M. Bunches must measure 7¾ in. across butts when green, 7½ in. when dry.

Grade D.—Six to ten-inch clear butts. Sap permitted.

15. 24″ Shingles 4/2″.—No shingle to be narrower than 2 in. Permits shims and feather tips 20 in. long. If packed by M must count 14/14 courses to bunch; 9 bunches to M. If packed by square, must count 14/14 courses to bunch, 4 bunches to square, 7½-in. exposure, and 3 bunches to square, 10-in. exposure. Bunches must measure 8¼ to 6¾ in. across butts when green, 6½ in. when dry.

16. 18″ Shingles 5/2¼″.—No shingle to be narrower than 2 in. Permits shims and feather tips 16 in. long. If packed by M, must count 20/20 courses to bunch, 5 bunches to M. Bunches must measure 8¾ in. across butts when green, 8½ in. when dry. If packed by the square must count 18/18 courses to bunch, 4 bunches to square. Bunches must measure 7⅞ in. across butts when green, 7⅝ in. when dry.

17. 16″ Shingles 5/2″.—No shingle to be narrower than 2 in. Permits shims and feather tips 14 in. long. If packed by M must count 25/25 courses to bunch, 4 bunches to M. Bunches must measure 9½ in. across butts when green, 9¼ in. when dry. If packed by the square must count 20/20 courses to bunch, 4 bunches to square, or 5 to M. Bunches must measure 7½ in. across butts when green, 7¼ in. when dry.

General Rules

18. All A- and B-grade shingles must be parallel (a 16 or 18-in. A or B shingle not over ¼ in. off parallel or a 24-in. A shingle not over ⅜ in. off parallel shall be considered parallel), uniform in thickness, and well manufactured. This means that shims and feather tips are not permitted; smoothness of faces and butts must be first class. Badly cross-grained shingles not permitted. The color of wood is not a defect in any grade.

19. No full flat-grain shingle wider than 10 in. permitted in grade B, and no shingle wider than 14 in. permitted in A and B grades; 1 in. over and under in length is permitted in 10 per cent of any shipment. Shingles cut from equalized blocks may be ¼ in. less than the standard length. C grade admits slight irregularities in thickness. A shingle in C grade not over ⅜ in. off parallel shall be considered parallel.

20.—When reference is made to edge grain, percentage of edge grain shall be determined by the proportion of actual linear measurement of edge grain to full linear measurement of shingles.

21.—In 16- or 18-in. A and B grades not more than 10 per cent of any shipment may be less than 4 in. in width.

22. All shingles to be packed in straight courses in regulation frames 20 in. in width with band sticks not less than 19½ in. long. Openings shall not exceed an average of 1 in. to the course in random-width shingles.

23. Discrepancy in inspection in any grade shall not exceed 4 per cent.

AMERICAN STANDARDS FOR SOFTWOOD FACTORY AND SHOP LUMBER

General Provisions

1. Grade by Cuttings.—The grade of factory and shop lumber shall be determined by the percentage of the area of each board or plank available in cuttings of specified or given minimum sizes and qualities, except in the upper grades of shop lumber of all thicknesses.

2. Grade Determined from Poor Face.—The grade of softwood factory boards or plank, and shop lumber, shall be determined from the poor face, although the quality of both sides of each cutting must be considered.

3. When lumber is crooked, bowed, cupped, or twisted, the cuttings must be so laid out as to be flat and straight along the edges.

4. Measurement, Fractions.—Board measurement shall be used in measuring factory and shop lumber. When measured with a board rule, pieces measuring to the even half foot shall be alternately counted as of the next higher and the next lower surface foot; fractions below the half foot shall be dropped, and fractions above the half foot shall be counted as of the next higher foot.

5. Thicker than 1 in.—To determine the board-foot contents of material thicker than 1 in., the surface measure should be multiplied by the nominal thickness in inches and fractions of an inch.

6. Based upon Rough Green.—The board measurement of dressed factory and shop lumber of standard size shall be based upon the corresponding standard dimensions of rough-green lumber.

Lumber Seasoning

7. Specifications dealing with lumber seasoning and moisture content shall be developed by each regional manufactuers' association in accordance with its own conditions and the requirements of the users of its products. Such specifications adopted from time to time by any regional

association shall be filed with the Central Committee on Lumber Standards for approval.

Basis of Measurement of Sizes

8. The dressed dimensions specified in paragraph 9 shall apply to lumber in the condition of seasoning as sold and shipped.

Dressed Thicknesses

9. The following thicknesses of factory and shop lumber shall be considered standard. All other thicknesses shall be considered special:

DRESSED THICKNESSES, S1S OR S2S

SIZE, BOARD MEASURE, INCHES	STANDARD FINISHED THICKNESSES, INCHES
1	$^{25}/_{32}$ and $^{26}/_{32}$
1¼	$1^{5}/_{32}$
1½	$1^{13}/_{32}$
2	$1^{26}/_{32}$
2¼	2⅛
2½	2⅜
3	2⅝
4	3⅝

NOTE.—It is to be understood that any association which publishes and administers rules for factory and shop lumber under the American Lumber Standards will not be required to furnish 1-in. factory lumber in both finished thicknesses.

Widths

10. Standard widths shall be 5 in. and over; factory and shop lumber is usually shipped in random widths, though specified widths may be shipped. Five-inch widths must be full size in the rough-dry condition.

Lengths

11. Standard lengths shall be 6 ft. and over in multiples of 1 ft., except in box lumber, which shall be 4 ft. and over.

FACTORY PLANK

12. Door Cuttings.—In determining the percentage of door cuttings, consideration must be given to the fact that planks are to be ripped full length before cross-cutting, in such manner as will yield the highest grade and largest percentage of door cuttings, except in cases where planks will yield a higher value by first being cross-cut for rails. In instances where stock is cross-cut for rails and some of the stock so obtained contains stiles or muntins or top rails, which can be obtained by ripping this cross-cut stock, the door cuttings so obtained may be figured in when determining percentages.

13. Basic Grade Classifications for Softwood Factory Plank

- **Factory Plank:** Factory lumber graded with reference to its use for doors, sash, and other cuttings
  - **Factory Clears:** Upper grades of factory plank containing a high percentage of best-quality cuttings
    - **No. 1 and 2 Clear Factory:** Lumber practically clear in wide sizes, to contain not less than 85 per cent of No. 1 door cuttings; not including pieces with over two muntins, or muntins only.
    - **No. 3 Clear Factory:** Lumber containing not less than 70 per cent of No. 1 door cuttings; not including pieces with over two muntins, or muntins only
  - **Shop:** Lower grades of factory plank yielding smaller percentages in smaller and lower-quality cuttings
    - **No. 1 Shop.** Lumber of high-quality factory grade containing not less than 50 per cent of No. 1 door cuttings; allowing, if necessary, one No. 2 stile in any piece but no pieces with over two muntins or muntins only
    - **No. 2 Shop:** Lumber containing not less than 25 per cent of No. 1 door cuttings, or 40 per cent of No. 2 door cuttings, or 33⅓ per cent of mixed door cuttings
    - **No. 3 Shop:** Lumber of a shop type below the grade of No. 2 shop and better than box lumber

Quality of Cuttings

14. No. 1 and No. 2 Cuttings.—In determining the grades of factory plank, two grades of cuttings shall be recognized. These shall be known as No. 1 and No. 2 cuttings and shall conform to the following rules:

15. No. 1 cuttings shall be free from defects on both sides. No restrictions shall be made upon bright sapwood.

16. No. 2 cuttings shall admit any one of the following defects:

Light-blue stain on one side, not larger in extent than one-half the area of the side.

Medium-brown kiln or heart stain covering half the surface on one face, or a greater area of lighter stain, or a proportionate amount on two sides.

A small, sound and tight knot which does not exceed ⅝ in. in diameter.

A small pitch pocket not over ⅛ in. wide nor over 2 in. long in West Coast woods and not over ⅛ in. wide nor over 1 in. long in Western pine and California pine.

One or more small season checks whose combined length does not exceed 8 in.

Light pitch or small pitch streaks that do not form a pronounced defect.

Slightly torn grain on one side.

Sizes of Cuttings

17. Size of Stiles.—Stiles shall be 5 and 6 in. wide by 6 ft. 8 in. to 7 ft. 6 in. long. They may be either No. 1 or No. 2 in quality.

18. Bottom Rails.—Bottom rails shall be 9 and 10 in. wide by 2 ft. 4 in. to 3 ft. long. They may be either No. 1 or No. 2 in quality.

19. Muntins.—Muntins shall be 5 and 6 in. wide by 3 ft. 6 in. to 4 ft. long. They may be either No. 1 or No. 2 in quality.

20. Top Rails.—Top rails shall be 5 and 6 in. wide by 2 ft. 4 in. to 3 ft. long. They must be of No. 1 cutting quality but shall be considered as No. 2 cuttings.

21. Sash Cuttings.—Sash cuttings shall be 2½ and 3½ in. in width by 28 in. and over in length.

22. Cuttings and Area Use.—In computing the area of cuttings in each piece of factory plank, the sizes listed on p. 76 shall be used. After each cutting size is shown the exact surface area in square feet. For convenience in computing, the figures shown on the right, representing the area to the nearest ¼ sq. ft., shall be used.

Size of cutting in board or plank	Actual area in square feet	Nominal area to be used in application of grading rules
Stiles		
5″ × 6′8″	2.78	3
5″ × 6′10″	2.85	
5″ × 7′0″	2.92	
5″ × 7′2″	2.99	
5″ × 7′4″	3.06	
5″ × 7′6″	3.13	
6″ × 6′8″	3.33	3¼
6″ × 6′10″	3.42	3½
6″ × 7′0″	3.50	
6″ × 7′2″	3.58	
6″ × 7′4″	3.67	3¾
6″ × 7′6″	3.75	
Bottom rails		
9″ × 2′4″	1.75	1¾
9″ × 2′6″	1.875	
9″ × 2′8″	2.0	2
9″ × 2′10″	2.125	
9″ × 3′0″	2.25	2¼
10″ × 2′4″	1.94	2
10″ × 2′6″	2.08	
10″ × 2′8″	2.22	2¼
10″ × 2′10″	2.36	
10″ × 3′0″	2.50	2½
Muntins		
5″ × 3′6″	1.46	1½
5″ × 3′8″	1.53	
5″ × 3′10″	1.60	
5″ × 4′0″	1.67	
6″ × 3′6″	1.75	1¾
6″ × 3′8″	1.83	
6″ × 3′10″	1.92	2
6″ × 4′0″	2.0	
Top rails		
5″ × 2′4″	0.97	1
5″ × 2′6″	1.04	
5″ × 2′8″	1.11	
5″ × 2′10″	1.18	
5″ × 3′0″	1.25	
6″ × 2′4″	1.17	1¼
6″ × 2′6″	1.25	
6″ × 2′8″	1.33	
6″ × 2′10″	1.42	1½
6″ × 3′0″	1.50	

Shop Lumber

23. Basic Grade Classifications for Softwood Shop Lumber.

	For Shop Lumber 1 In. in Thickness[1]	For Shop Lumber of All Thicknesses[2]
Shop Lumber Shop lumber graded for cuttings of minimum and larger sizes, or for permissible defects, with reference to its use for general cut-up purposes	Select: Lumber to contain not less than 70 per cent of A and/or B cuttings. Shop: Lumber to contain not less than 50 per cent of A and/or B cuttings.	Tank and Boat Stock: Lumber admitting sound defects that do not impair the usefulness of each piece for the use intended. Firsts and Seconds: Lumber of C select or better quality on the reverse side, suitable for remanufacture into products requiring both faces of good quality. Selects: Lumber of C select or better quality on the face side suitable for remanufacture into products requiring one face of good quality. No. 1 Shop: Lumber to contain not less than 60 per cent of (*a*) and/or (*b*) cuttings. No. 2 Shop: Lumber to contain not less than 40 per cent of (*a*) and/or (*b*) cuttings. Box: Lumber below the grade of No. 2 shop, to contain not less than 66⅔ per cent sound cuttings not less than 3 in. wide and 18 in. long.

[1] For northern, western, and California pine, and west coast woods.
[2] For cypress, redwood, and North Carolina pine.

24. Determining Grades.—In determining the grades of either shop or cut-up lumber based on cuttings, two grades and sizes of cuttings shall be recognized and shall conform to the following rules:

Sizes of Cuttings

25. (*a*) Cuttings shall be 9½ in. wide or wider by 18 in. long or longer

26. (*b*) Cuttings shall be 5 in. wide or wider by 3 ft. long or longer.

Quality of Cuttings

27. (*a*) Cuttings less than 3 ft. long shall be free from all defects on both sides. No restriction need be made upon bright sapwood.

28. (*a*) Cuttings 3 ft. long or longer and (*b*) cuttings shall have a C select or better face in all softwoods except Douglas fir, Sitka spruce,

and west coast hemlock, where the face of the cuttings shall be equal to B or better finish.

LUMBER INSPECTION PROVISIONS AND SERVICE

1. Acceptance.—Lumber must be accepted on grade in the form in which it is shipped. Any subsequent change in manufacture, millwork, or drykilning will prohibit an inspection for the adjustment of claims, except with the consent of all parties interested.

2. Inspection Availability.—Official association inspection service for the inspecting of lumber sold as of standard size and standard grade shall be available to non-members of associations upon request and at a reasonable charge.

3. Reinspection.—In case of complaint on account of the grade or tally of any shipment of standard size or standard grade, official association reinspection shall be available.

4. Special Grades.—Official association inspection service shall not be required to be furnished for the inspection of "special" grades of lumber (that is, not recognized in published grading rules), and inspection service for "special" grades shall be furnished only when the exact specifications of such grades in writing are furnished to the inspector.

5. Certificate.—Where buyers demand, and will pay the cost thereof, a certificate made by a certified association inspector shall be furnished with each shipment so arranged for.

6. Complaint and Reinspection.—Upon receipt of complaint from the purchaser, the seller shall immediately request the association under whose rules shipment has been made to provide official reinspection or retally, as the case may be, according to its inspection rules in effect at the time of execution of contract; and the purchaser shall lend all reasonable assistance to facilitate the reinspection or retally.

7. Expense of Inspections.—The expense of such reinspection or retally may be divided between the buyer and seller, or may be borne by either, according to agreement between them, but the person calling for the reinspection shall be responsible to the association for the costs thereof.

8. Complaint on Tally.—In case of complaint involving tally, the entire item shall be held intact for retally.

9. Complaint on Grade Only.—In cases of complaint regarding grade but not involving tally, the buyer is required to accept that portion of a shipment of lumber of standard grade or standard size, which is up to grade or of standard size, as the case may be, holding intact that portion thereof the grade or size of which is in dispute for official association inspection; the action on the part of the buyer in accepting and using such portion of the shipment shall not be construed as his acceptance of the entire shipment; further, the buyer shall pay in accordance with the

terms of sale for that portion which he accepts, but acceptance by the buyer of a part of a shipment does not prejudice his just claims on account of any unused material that is alleged by him to be below standard grade or not of standard size.

10. Shipment to Be Held Not Exceeding 30 Days.—The complainant buyer shall hold disputed material intact, properly protected, for not exceeding 30 days after date of the request for official inspection or reinspection, and shall file complaint with seller within 10 days from receipt of shipment.

11. Variation of Inspections.—Each item in a carload or a cargo shall be considered as of the grade invoiced if, upon official association reinspection under the grading and inspection rules under which the lumber has been graded and sold, 95 per cent thereof or more is found to be of said grade, the material below said grade to be accepted by the buyer as of its actual grade. Where the degrades are in excess of 5 per cent of such item, or where the degrades are found upon official reinspection to be more than one grade lower than the grade invoiced, the degrades shall be the property of the seller. These provisions shall not apply in the case of specially worked lumber.

12. Central Bureau to Promote High Standards.—There shall be created by the lumber manufacturers a central bureau to promote uniformity and the maintenance of high standards of grading and inspection of lumber.

13. Plan of Operation.—Each manufacturers' association publishing lumber-grading rules and conducting inspection service shall furnish to such central bureau complete information descriptive of the plan of operation and continuous regular reports of its inspection department.

14. Coordination of Methods of Inspection.—In order to simplify, coordinate, and, so far as practicable, unify the methods of inspection, each such association shall be furnished by such central bureau the plan of operation and the record of performance of the inspection service of each other association.

15. Arbitration of Complaints.—In pursuance of national responsibility of the lumber industry for the maintenance of agreed American Lumber Standards, if, after original association inspection, reinspection, and if necessary after reinspection and a report thereon of the chief inspector, any complaint involving agreed and published standards of lumber size, or grade, or inspection shall not have been settled, the National Lumber Manufacturers Association, by agreement or upon request, will represent the manufacturing shipper in arrangement for arbitration.

16. Administration of Inspection.—The National Lumber Manufacturers Association will represent, by agreement, the subscribing regional associations of lumber manufacturers and other associations of, or representing, lumber manufacturers, upon request, in matters involving

the administration of inspection and the maintenance of the agreed standards of lumber size and lumber grade designated as American Lumber Standards.

17. Formulation of Inspection Regulations.—The formulation of regulations for the conduct of inspection to secure the application of the grading rules published by lumber associations, and the administration, supervision, and conduct of inspection service, be exclusively by the lumber industry, and/or lumber consumers (that is, by the agencies of the lumber trade, and/or lumber consumers, and not by or under the authority, auspices, or direction of any government agency or agencies).

18. National Inspection Not Practical.—Nationally administered association lumber inspection, in the sense of a national service to replace the existing services of regional and other associations, is not now practicable.

19. Reinspection.—Each association shall undertake to reinspect lumber for its members, and for nonmembers upon request.

20. Qualified Inspectors.—All grading shall be done by properly supervised and qualified graders or inspectors.

21. Maintenance of Standards.—So far as it is within their power, the associations within the lumber industry shall undertake, through association grades and inspection service, arbitration, and, if practicable, through grade marking and otherwise, to maintain for the benefit of the lumber-using public the standards of size and basic grade names and classifications as agreed upon and as published in the association grading and inspection rules.

22. The associations which make grading rules and conduct lumber inspection service shall maintain such size, grade, and inspection standards as may have been agreed to.

23. Each such association shall assume responsibility for the maintenance in the manner herein outlined, by its individual members or subscribers, of said size standards, basic-grade classifications, and inspection standards.

24. The principle of responsibility of the entire organized lumber industry for the maintenance of agreed and published size, grade, and inspection standards is recognized; and for the suitable discharge of such responsibility the Central Committee on Lumber Standards or similar suitable agency shall be continued.

25. Lumber manufactured, graded, measured, and described, as herein provided, shall be considered American Standard lumber. The purchase, sale, or shipment of lumber as American Standard is construed as involving agreement to submit to official association inspection any complaint involving either standard sizes or standard grades.

26. Contract Clause.—Sales contracts should incorporate in substance the following clause:

"Shipment under this contract shall be in accordance with the American Lumber Standards."

27. Exemption.—In case of shipments made or received under such contracts, exemption from any provision of the American Lumber Standards shall be by special agreement and the burden of proof thereof shall be upon person claiming exemption.

BASIC GRADING PROVISIONS FOR STRUCTURAL TIMBERS

Tables of working stresses for structural timbers abound in engineering literature and form a part and substance of the building codes of most of our larger cities; but there has been a lack of uniformity in the values for any given species.

City building codes have, until recently, quite generally given a single working stress for a species without indicating the quality or grade of lumber for which the stress is allowed. The description of minimum quality of the material, if specified, was usually general and inadequate, though at times requiring material of a character impossible to obtain. The absence of properly drawn structural timber grading rules, on which the establishment of suitable working stresses is dependent, accounts in part for this condition. Incorrect specifications result in either poor construction or poor utilization. When the stress allowed is too high, the timbers are too small to carry the loads for which they are designed, and even when they do not fail completely, they result in unsatisfactory structures. When the working stresses are too low for the grade furnished by the local market, the results are a waste of timber and needlessly expensive construction.

Strength Dependent on Grading

Decision as to the species of timber to purchase for a definite structural use is now generally based on the reputation of the species for strength, regardless of the grade or defects of the timber or its specific suitability for the purpose intended. Such a method of selection often fails to insure the use of the most suitable material, for the reason that the defects present may cause a much wider range in strength than the inherent differences in the clear wood of the various species would cause.

It is impractical to assign correct working stresses to commercial grades for timbers which do not specifically limit the defects or cover the density and inherent quality from the standpoint of strength, nor is it practical to establish working stresses by testing various grades of each species as found in the local market, owing to the vast amount of testing required, the expense involved, and the continually changing character of the material which may be submitted under grades not written for the purpose of selecting material for strength.

There is always a considerable range in value between the strongest piece of timber which may be obtained under a given rule and the weakest timber which would be allowed under the same rule. The most efficient grading rule is one which eliminates the maximum amount of undesirable material and a minimum amount of material having the required properties.

Average values for the strength of timber of a given grade which is not specifically a structural grade have little significance, since they are largely dependent upon the class of timber being cut and the demand for the various sawmill products.

If the current demand for lumber is stronger than that for structural timber, the inclination will be to ship on the basis of the general use grade rather than on the structural grades. Under the reverse condition the quality of the material shipped for structural uses will naturally be raised.

The minimum strength of structural timbers depends more upon their grade than upon the species of timber. The maximum strength which may be obtained is limited by the strength of the clear wood of the maximum density found in the species and varies largely with the species. The species showing the greatest density has, inherently, the greatest strength, but the strength of a dense timber may be offset by defects, so that a piece of a species of less density but containing smaller defects may have greater strength. It is possible to make structural grades which are applicable to all species, for defects which affect strength have, in general, the same effect in all species. This is not the case with general grades, based on the specific defects of a species and, largely, on appearance rather than strength. Efficient grading rules raise the standard of quality for the better grades, and by insuring to the customer the quality of the material desired for a given purpose, they tend to promote the efficient use of wood. At the same time they insure a better market for the higher grades of material without encroaching upon the markets for the lower grades.

FOUR BASIC GRADES

A set of basic grade provisions and working stresses for structural timbers is presented in this chapter as a step toward standardization and more efficient utilization. These provisions and working stresses are based on results obtained by the Forest Products Laboratory from hundreds of thousands of tests of small, clear specimens, from numerous tests of structural timbers containing defects, and from other intimate studies of the various species involved.

They have been adopted by the lumber industry in cooperation with all organized wood-using groups and are known as *Basic Provisions for Structural Material of American Lumber Standards.* They furnish a sound basis for efficient lumber utilization in building and construction.

In substance, they provide for a simple classification of any or all species into four basic structural grades from the standpoint of strength requirements for various structural purposes, called Dense Select, Select, Dense Common, and Common. The difference in inherent strength and character of various species is taken care of in the recommended working stresses.

The Select basic grade is primarily suitable for general bridge and building use and factor or slow-burning heavy timber construction. The Dense Common and Common grades are especially recommended for small house construction where stiffness is a controlling factor and where strength requirements are not so critical. These classes furnish the greater portion of structural timbers used. Dense Select material is of exceptionally high quality and is intended to meet the most exacting strength requirements for construction purposes.

The basic grades were developed primarily upon the size, number, and location of permissible defects, which are limited and classified in a practical way for different parts of a beam, in accordance with the economic requirements for different classes of use. The maximum sizes of knots permissible in the grades bear a simple relation to each other. Working stresses have an equally simple relation, which is dependent upon the size of allowable defects. Differences between light and dense material, in the case of Douglas fir and southern pine, are taken care of by increased working stresses for dense stock.

Specific limitation of defects affecting strength is a fundamental basis for the development of these rules; hence, safe working stresses can be given with assurance. Upon the basic grades can be formulated commercial grades which include provision for such other requirements for particular uses as may be desirable for other than strength purposes.

Durability

The basic provisions do not control the factors that influence durability. Specifications for timbers which are to be subjected to conditions favorable to decay should take these factors into account. Much can be accomplished toward prevention of decay under such circumstances by selecting durable species and permitting only a small percentage of sapwood. In case the lowest basic grade is used under conditions favorable to decay, no infected or decayed material should be permitted, except a very few types of rot which are known not to progress appreciably after the tree is felled. The percentage of sapwood allowed should be definitely stated, with directions as to how it shall be measured. When preservative treatment is to be applied there should be no restriction as to sapwood, as sapwood is easier to treat than heartwood, and a large amount is to be preferred. Knot holes, shakes appearing on the surface, and

other defects which will collect and hold moisture should also be restricted in timbers which are to be used in wet or damp locations.

FACTORS AFFECTING BASIC GRADES

The purpose of structural grades is to offer means for selecting structural material for strength, and for assured minimum strength in order that appropriate working stresses may be assigned.

The most important factors which influence the strength of structural material are the density (or dry weight), the moisture content, the size, number and location of defects, and the extent of exposure to moisture during use. These factors must all be considered in design or grading if the maximum utilization is to be obtained from the material used.

The basic grade provisions control defects by limiting their size and location in accordance with their effect upon strength; and working stresses for each species are recommended by the Forest Products Laboratory, United States Forest Service, which take into consideration the allowable defects, the density, and the moisture content as determined by conditions of use.

Influence of Knots

The principal defects which must be limited in structural grades are knots, shakes and checks, and slope of grain.

The influence of a knot in a beam is determined by its location and the area of its projection on the cross-section of the piece—the method of measurement being such as to give the best approximation of this influence. Knots in posts and large beams are likely to show on one face only or to run diagonally through the piece and reduce the strength in practically direct proportion to their size as measured. In dimension sizes, such as joist, the knot is likely to run directly through the piece, and the strength is measured by the square of the effective depth of the piece, assuming the knot in its worst position, which is near the edge of the piece. The proportional reduction in strength due to the knot is approximately double the ratio of the size of the knot to the width of the face. In similar material used flat, as plank, the influence of a knot is directly proportional to the size, as on the top and bottom edges of beams.

Knot limitations on edges of wide faces of dimension sizes, for use as joist, are more severe than would be required for use flat, as plank, the sizes applying along the center lines of the wide faces as joist being those which could theoretically apply at any point across the width if used only as plank. It has been found, however, that under practically all conditions of use, knots along the edges of planks are more objectionable than knots along the center lines, and this is recognized in some commercial yard grades of plank in a stricter limitation of knots along the edges of wide faces than along the center lines. The same knot limitations are

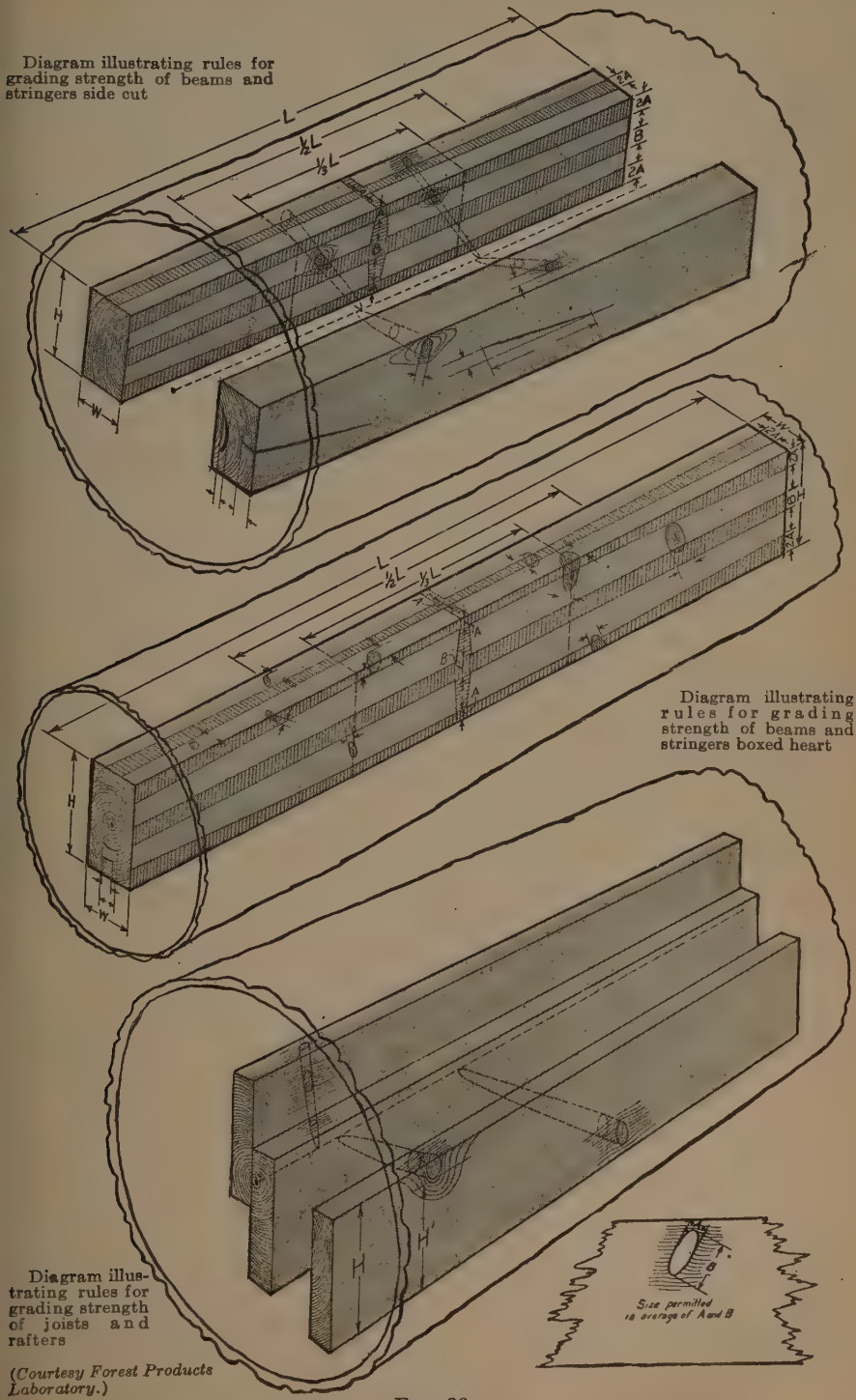


Diagram illustrating rules for grading strength of beams and stringers side cut

Diagram illustrating rules for grading strength of beams and stringers boxed heart

Diagram illustrating rules for grading strength of joists and rafters

(Courtesy Forest Products Laboratory.)

FIG. 26.

applied, therefore, to material to be used either as joist or plank, and the same working stresses are assigned for use either on edge or on flat.

In both joists and beams, knots reduce strength most along the top and bottom edges, through the center portion. The sizes of knots permitted in various portions of a joist or beam are limited in accordance with the stresses, and they are allowed to increase toward the ends and toward the center lines of the vertical faces—no knots, however, being permitted to increase to more than double the size allowed at the point of maximum stress.

There is greater proportional distortion of grain around a large knot than around a smaller one, and shrinkage in seasoning causes greater internal stresses, so knot sizes are increased proportionately to width of faces only up to 6-in. top and bottom faces of beams, 12-in. vertical faces of beams, and 12-in. faces of dimension and posts. Beyond these widths of face, increase is proportional to the square root of the ratio of the wider faces to these widths. The distribution and aggregate diameter of knots is limited, as well as the maximum size of the single knot.

The aggregate diameter of all knots in the center half of the length of any face of a beam or stringer is limited, in direct proportion, to an aggregate diameter of twice the width of the face in a grade having 50 per cent of the strength of clear wood. In joist and plank, in dry locations, the aggregate diameter of knots in the center half of the length of any face may be greater by one-half the width of the face than the aggregate diameter permitted in beams and stringers. In posts and columns, the aggregate diameter of all knots in any 6 in. of length, in any grade, is limited to twice the size of the maximum knot allowable.

In joist and plank, the mean or average diameter of a knot is taken as its size. In such thin and relatively wide material, whether used on edge or flat, this is a safe measure of the influence of knots on strength and has the commercial advantage of being directly applicable to yard grades of lumber. This method of measurement will exclude damaging spike knots and can be applied to them as well as to round or oval knots.

On the top or bottom of a beam, the influence of knots is measured largely by the surface fibers cut. Therefore the projection of the knot on a line at a right angle to the edge is used. On the vertical face of a beam, the depth to which a knot penetrates is of great importance, while the influence of the number of surface fibers cut, and the amount of grain distortion, is considerably less important than on the horizontal faces. Therefore, the smallest diameter of the knot is used.

One of the best illustrations of the reason for using the smallest diameter on the vertical face is in the splitting of a boxed-heart timber into two pieces. The long spike knots which might be opened up in this way would be no more injurious to the strength of the two pieces than they would as a single knot in a boxed-heart piece, and the two pieces so

cut would be less subject to seasoning checks than a boxed-heart piece.

In columns there are two factors: area of cross-section occupied by a knot—which would probably be measured best by the small diameter of the knot—and the influence of bending stresses when the column begins to fail—probably measured best by the projection of the knot. In short columns, the area of the cross-section is of primary importance; as the column gets longer, the factor of bending strength increases in importance until the condition of the Euler formula is reached, when stiffness, on which knots have practically no influence, becomes the ruling factor. The average diameter, therefore, is used as that which applies best to the average condition.

In grades for structural uses, no distinction is made between intergrown knots and encased knots or knot holes, observation at the Forest Products Laboratory having shown that intergrown knots reduce strength fully as much as encased knots or knot holes.

Shakes and Checks

Shakes reduce the area of a beam acting in resistance to shear, and the limitations placed on shake are based on this reduction. Checks are limited on the same basis as shakes, and no combination of shakes and checks is permitted which would reduce strength to a greater extent than would the allowable size of either separately. Shake in green material is assumed to reduce shearing stress in direct proportion to its extent. A greater amount of shake is permitted in seasoned material, made up for by the increased resistance of the remaining cross-section when seasoned. In joist and plank, and beams and stringers, shake in green material is permitted in direct proportion of increase from none in a grade of the strength of green, clear wood to one-half the width of the piece in a grade having one-half the strength of green, clear wood. In seasoned material, shake is similarly permitted from one-ninth the width of the piece in a grade of the strength of green, clear wood to five-ninths the width of the piece in a grade having one-half the strength of green, clear wood.

Shakes and checks, as a rule, have little influence on the strength of columns, unless they are so extensive as to split a column practically in two. Limitation of shakes and checks in columns is more important from the standpoints of appearance and of reducing opportunity for decay. In post and timber grades, shake in green material is permitted in direct proportion of increase from two-tenths the width of the piece in a grade of the strength of green, clear wood to sixth-tenths the width of the piece in a grade having one-half the strength of green, clear wood. In seasoned material, shake is similarly permitted from three-tenths the width of the piece in a grade having the strength of green, clear wood to seven-tenths the width of the piece in a grade having one-half the strength of green, clear wood.

Slope of Grain

Slope of grain, resulting either from diagonal sawing or from spiral or twisted grain in the log, is limited in accordance with the recommendations of the Forest Products Laboratory based on the results of detailed study of the effect of cross- and spiral-grain upon strength and the weakening of material by checks which invariably develop and without exception follow the grain.

There is not much reduction in strength from cross-grain in a beam until a slope of 1 in 40 is reached. From that slope in a beam of a grade having the strength of green, clear wood, slope of grain is limited to 1 in 20 in a grade having seven-eighths this strength to 1 in 15 in a grade of three-fourths, 1 in 11 in a grade of five-eighths, and 1 in 8 in a grade of one-half the strength of green, clear wood.

In a post or column the influence on strength of cross-grain and of the checks following the grain is much less than in a piece in bending, but excessive cross- or spiral-grain is objectionable on account of the twisting and diagonal checks which occur in seasoning. Slope of grain in a post or column is limited to 1 in 20 in a grade having the strength of green, clear wood, 1 in 15 in a grade of seven-eighths this strength, 1 in 11 in a grade of three-fourths, 1 in 8 in a grade of five-eighths, and 1 in 6 in a grade having one-half the strength of green, clear wood.

Slope of grain should be measured over a distance which will assure the determination of the general slope of the grain not influenced by short, local deviations. In a piece in bending, it is of greatest importance on the top and bottom faces. If meeting the limitation of a grade in these locations, it may be somewhat greater elsewhere.

Wane

Wane is limited by such considerations as bearing area, nailing edge, appearance, etc., rather than by effect on strength. The percentage reduction in strength resulting from wane toward the center of the length of a beam is about double the percentage reduction in cross-sectional area. No combination of wane and knots is permitted which reduces the strength more than the maximum allowable knot. The occurrence of maximum wane and maximum knot in the same cross-section at the center of a beam would be so rare, however, and the effect of the allowable maximum wane is so small a percentage of the effect of the maximum allowable knot, that the additional reduction in strength beyond the effect of the knot would be slight. It is usually unnecessary to give attention to a combination of wane and knots.

Pitch Pockets

Pitch pockets are not, ordinarily, defects in a structural grade. A large number, however, indicates a general lack of bond, and such a piece should be carefully examined for shakes.

Density and Rate of Growth

The density of the wood substance of all species is practically the same as noted in Chap. I. The dry weight is, therefore, a measure of the amount of wood substance present; and on the amount of wood substance present depends the strength of the clear wood. No pieces of exceptionally light weight are permitted in any grade, but pieces considered too light for a particular grade, but of that grade otherwise, may, in general, be accepted in a lower grade.

In southern pine and Douglas fir, the proportion of summerwood, the dark portion of the annual ring, furnishes a practical means of estimating density. Selection of these species for density, to the extent that dense material is commercially available, assures material of the highest character from the standpoint of strength, and uniformity in strength, in the clear wood.

Selection of Douglas fir for rate of growth is not so great an assurance of increased strength as selection for percentage of summerwood; but for many purposes selection for rate of growth will assure material of suitable type.

In acceptance for density, the contrast in color between summerwood and springwood should be distinct. Absence of contrast occasionally occurs in bands of growth rings which appear, on the whole, darker in color than the adjacent material. The summerwood merges into the springwood abnormally with a gradual change of color, leaving practically no material which has the normal appearance of springwood. Such material has been called by a number of names, including *proudwood*, *redwood*, and *compressionwood*. It has a decided end shrinkage, is weak in tension, and material of this character in even a small part of a cross-section is undesirable in high-class structural timbers.

Structural grades specify minimum requirements and maximum defects, all of which may be present at one time. Therefore, when a particular piece which is being inspected is slightly below the provisions of the grade in some respects but is of average density or above, the relative effect on the properties affected should be given consideration.

In inspection for density, reasonable variation of opinion among inspectors should be recognized. A fair provision for reinspection of a particular lot of timbers for density is that given on pages 93 and 94; namely, that for every three timbers accepted as having one-third or more summerwood, one of the remaining timbers be accepted if having between 30 and 33⅓ per cent summerwood.

A large percentage of material in standard yard grades of dimension and timbers will meet the additional requirements of structural grades for joist and plank, and posts and timbers, and material to meet these requirements can easily be selected from local stocks. Beams and stringers vary

materially in size and are not stocked extensively. These are essentially special-order grades.

Moisture

Since increase in strength due to loss of moisture (see p. 23) is accompanied by checking, splitting, warping and twisting some of the strength due to drying is lost. The strength of green wood is, therefore, used as the basis of working stresses. Timbers are also subject, during use, to varying conditions of moisture, from the dry location of a heated building, to the continually wet condition of some pier and dock timbers. All of these conditions are taken into account in the recommended working stresses under different conditions of use.

In dimension lumber 4 in. and less in thickness, the development of defects during seasoning does not offset the increase in strength from drying so much as in larger sizes, and in these sizes used in dry locations, higher working stresses in extreme fiber in bending can be recommended than in pieces of larger size having proportionately equivalent defects

AMERICAN STANDARDS FOR STRUCTURAL MATERIAL

Basic Provisions for the Selection and Inspection of Softwood Dimension and Timbers Where Working Stresses are Required

The following provisions are for use as a basis for the preparation by lumber manufacturers of grading rules for structural material. It is understood that these basic provisions are not to be used as grading rules but are merely a standardized working basis to enable manufacturers of the various species to coordinate their grades as far as possible. Producers of structural material are providing structural grades in conformity with these basic provisions and such material can now be bought on manufacturers' standard structural grades.

I. Basic Grade and Use Classifications

1. Basic grades: (*a*) Dense select.
Douglas fir and southern pine.
(*b*) Select Douglas fir.
(*c*) Select.
Other softwood species except southern pine.
(*d*) Dense common.
Douglas fir and southern pine.
(*e*) Common.
All softwood species.

2. Use classifications: (*a*) Joist and plank.
Joists, rafters, plank, factory flooring, etc.
(*b*) Beams and stringers.
Beams, girders, stringers, etc.
(*c*) Posts and timbers.
Posts, caps, sills, other timbers, etc.

II. Optional Provisions

3. No heartwood requirements are provided in these grades. Heartwood, when desired for durability of untreated timber, should be specified in terms of heartwood required on the girth or on each face, side, or edge. Girth shall be measured at the point where the greatest amount of sapwood occurs.

4. For material to be treated, a large amount of sapwood is to be preferred. It is not practicable to specify a minimum sapwood requirement, but it could be noted that there is no restriction on sapwood.

5. Wane is permissible in all grades, as far as strength properties are concerned, but square edges may be specified when appearance, bearing, or other factors of use require.

III. General Provisions

6. Sound Wood.—All grades shall contain only sound wood, free from any form of decay, incipient or advanced, including firm red heart, dote, and rot.

7. Definitions of Faces and Edges.—The faces of a piece of dimension or of a timber are the four longitudinal surfaces of the piece, sometimes further designated as *wide* faces or *narrow* faces.

8. In a piece of dimension or a timber graded for use in bending, wide faces shall be taken as vertical faces, and narrow faces as horizontal faces, unless otherwise noted.

9. When the faces of a piece of dimension or of a timber are of equal width, post-and-timber grades shall be used unless otherwise noted. When such a piece of dimension or such a timber is graded for use in bending, the best faces shall be taken as the horizontal faces and should be so marked.

10. The edges of a piece of dimension or of a timber are understood to be the narrower faces, and the sides the wider faces. In describing the locations of knots and other defects in structural material, however, the edges of a given face are understood to be the intersection of two adjacent faces, in the past commonly called *corners*.

11. Knots.—The size of a knot shall be measured on the section of the knot appearing on the face under consideration.

12. On narrow faces of joist and plank, and on narrow or horizontal faces of beams and stringers, the size of a knot shall be taken as its width between lines parallel to the edges of the piece.

13. On wide or vertical faces of beams and stringers, the smallest diameter of a knot shall be taken as its size.

14. Knots at edges of wide or vertical faces of beams and stringers are limited to the same size as on adjacent narrow or horizontal faces, but the size is measured on the least diameter of the knot instead of on its width between lines parallel to the edges of the piece.

15. In posts and timbers, and on wide faces of joist and plank, the size of a knot shall be measured on the mean or average diameter. The mean or average diameter of a knot shall be taken as the average of the maximum and minimum diameters.

16. The size of knots on narrow faces and at edges of wide faces of joist and plank and on narrow or horizontal faces and at edges of wide or vertical faces of beams and stringers may increase proportionately from the size allowed in the middle third to twice that size at the ends of the piece.

17. The size of knots on wide faces of joist and plank and on wide or vertical faces of beams and stringers may increase proportionately from the size allowed at the edge to that allowed at the center line.

18. Cluster knots and knots in groups are not permitted.

19. Knot holes and holes from other causes than knots shall be limited as provided for knots.

20. Shakes and Checks.—Shake shall be measured on the ends of a piece.

21. In joist and plank, and in beams and stringers, the size of a shake shall be taken as the shortest distance between lines enclosing the shake and parallel to the wide faces of the piece.

22. In posts and timbers, the size of a shake shall be measured between lines parallel to each pair of opposite faces, and the greater of these two distances shall be taken as its size.

23. Checks and splits shall be limited as provided for shakes. No checks or combinations of checks with shakes shall be permitted which would reduce the strength to a greater extent than the allowable shake.

24. Slope of Grain.—Slope of grain shall be measured over a distance which will assure the determination of the general slope of the grain not influenced by short, local deviations. In a piece in bending, it is of greatest importance on the top and bottom faces. If meeting the limitation of a grade in these locations, it may be somewhat greater elsewhere.

25. Pitch Pockets.—Pitch pockets are ordinarily not defects in a structural grade. A large number, however, indicates a general lack of bond, and such a piece should be carefully examined for shakes.

26. Wane.—Where wane is permitted, there shall be no combination of wane and knots which would reduce the strength more than the maximum allowable knot.

27. Weight.—No pieces of exceptionally light weight shall be permitted in any grade.

28. Methods of Measurement.—Methods of measurement for density of Douglas fir and southern pine are given for use with the dense grades. Methods of measurement for rate of growth shall be given for use in the case of species and grades where close grain is required.

29. The dressed dimensions specified in paragraphs 35, 43, and 50, shall be minimum dimensions when measured green.

IV. Density and Close Grain

30. Dense Douglas Fir.—Douglas fir of dense material shall average on either one end or the other not less than six annual rings per inch and, in addition, one-third or more summerwood, the darker, harder portion of the annual ring, measured over a 3-in. portion of a radial line located as described below. The contrast in color between summerwood and springwood shall be distinct.

Coarse-grained material excluded by this rule shall be accepted as dense if averaging one-half or more summerwood.

In inspection for density, reasonable variation of opinion between inspectors must be recognized. In reinspection of a particular lot of timbers for density, for every three timbers accepted as having one-third or more summerwood, one of the remaining timbers shall be accepted if agreed upon as having between 30 and 33⅓ per cent summerwood.

31. Close-grained Douglas Fir.—Douglas fir of close grain shall average on either one end or the other not less than 6 nor more than 20 annual rings per inch, measured over a 3-in. portion of a radial line located as described below. Pieces averaging from 5 to 6 annual rings per inch shall be accepted as equivalent of close grain if having one-third or more summerwood.

32. Location of the Radial Line in Douglas Fir.—The radial line shall be representative of the average growth on the cross-section.

When the radial line specified is not representative, it shall be shifted sufficiently to present a fair average, but the distance from the pith to the beginning of the 3-in. portion of the line in boxed-heart pieces shall not be changed.

In case of disagreement, two radial lines shall be chosen, and the number of rings per inch or percentage of summerwood shall be the average determined on these lines.

In side-cut pieces, the radial line on which percentage of summerwood or close grain shall be measured shall be at a right angle to the annual rings, and the center of the 3-in. portion of the line shall be at the center of the end of the piece.

In boxed-heart pieces, the line shall run from the pith to the corner farthest from the pith. When the least dimension is 6 in. or less, the 3-in. portion of the line shall begin at a distance of 1 in. from the pith. When the least dimension is more than 6 in., the 3-in. portion of the line shall begin at a distance from the pith equal to 2 in. less than one-half the least dimension of the piece.

If a 3-in. portion of a radial line cannot be obtained, the measurement shall be made over as much of a 3-in. portion as is available.

33. Dense Southern Pine.—Southern pine of dense material shall average on either one end or the other not less than six annual rings per inch and, in addition, one-third or more summerwood, the darker, harder portion of the annual ring, measured over the third, fourth, and fifth inches of a radial line from the pith.

The contrast in color between summerwood and springwood shall be sharp and the summerwood shall be dark in color, except in pieces having considerably above the minimum requirement for summerwood.

Coarse-grained material excluded by this rule shall be accepted as dense if averaging one-half or more summerwood.

In inspection for density, reasonable variation of opinion between inspectors must be recognized. In reinspection of a particular lot of timbers for density, for every three timbers accepted as having one-third or more summerwood, one of the remaining timbers shall be accepted if agreed upon as having between 30 and 33⅓ per cent summerwood.

34. Location of Radial Line in Southern Pine.—The radial line shall be representative of the average growth on the cross-section.

In boxed-heart pieces, the measurement shall be made over the third, fourth, and fifth inches from the pith along the radial line.

In case of disagreement, two radial lines shall be chosen, and the number of rings per inch or percentage of summerwood shall be the average determined on these lines.

In cases where timbers do not contain the pith and it is impossible to locate it with any degree of accuracy, the same inspection shall be made over 3 in. on an approximate radial line beginning at the edge nearest the pith in timbers over 3 in. in thickness and on the second inch nearest to the pith in timbers 3 in. or less in thickness.

In material containing the pith but not a 5-in. radial line, which is less than 2 by 8 in. in section or less than 8 in. in width, that does not show over 16 sq. in. on the cross-section, the inspection shall apply to the second inch from the pith. In larger material that does not show a 5-in. radial line, the inspection shall apply to the 3 in. farthest from the pith.

V. Joist and Plank

Joists, Rafters, Plank, Factory Flooring, Etc.

35. Nominal thicknesses: 2 to 4 in.

Nominal widths: 4 in. and wider.

Standard thicknesses, S1S or S2S: ⅜ in. off.

Standard widths, 4 to 7 in., S1E or S2E: ⅜ in. off; 8 in. and wider, S1E or S2E: ½ in. off.

Standard lengths: Multiples of 2 ft.

36.

KNOTS ON WIDE FACES

Dense Select and Select		Width of face, inches	Dense Common and Common	
On or near edge of wide face middle third of length, inches	Center line of wide face, inches		On or near edge of wide face middle third of length, inches	Center line of wide face, inches
¾	1¼	4	1	1¾
1	2	6	1½	2½
1⅜	2⅝	8	2	3⅜
1¾	3¼	10	2½	4¼
2⅛	4	12	3	5⅛
2⅜	4¼	14	3¼	5⅝
2½	4⅝	16	3⅜	6

37.

KNOTS ON NARROW FACES OF BOXED-HEART PIECES, MIDDLE THIRD OF LENGTH

Dense Select and Select, inches	Thickness of piece, inches	Dense Common and Common, inches
⅝	2	⅞
1	3	1¼
1¼	4	1¾

38.

SUM OF DIAMETERS OF KNOTS ON ANY FACE, CENTER HALF OF LENGTH, NOT TO EXCEED

Dense Select and Select	Dense Common and Common
One and one-half times width of face	Two times width of face.

39.

SHAKES AND CHECKS

Dense Select and Select		Dense Common and Common
One-fourth width of end	Green	Four-tenths width of end
One-third width of end	Seasoned	Four-ninth width of end

40.

SLOPE OF GRAIN, CENTER HALF OF LENGTH

Dense Select and Select	Dense Common and Common
1 in 12	1 in 10

41.

WANE

Dense Select and Select	Dense Common and Common
One-eighth width of any face	One-fourth width of any face

42. Douglas fir or southern pine of dense grades shall be selected for density. Douglas fir of select grade shall be selected for close grain.

VI. BEAMS AND STRINGERS

Beams, Girders, Stringers, Etc.

43. Nominal thicknesses: 5 in. and thicker.
Nominal widths: 8 in. and wider.
Standard lengths: Multiples of 2 ft.
S1S, S1E, S2S, or S4S: ½ in. off each way.

44.

KNOTS

Dense Select and Select			Dense Common and Common	
Narrow or horizontal face and edge of wide face middle third of length, inches	Center line of wide or vertical face, inches	Width of face, inches	Narrow or horizontal face and edge of wide face middle third of length, inches	Center line of wide or vertical face, inches
1¼	1¼	5	2	2
1½	1½	6	2⅜	2⅜
1¾	2	8	2¾	3⅛
2	2½	10	3⅛	4
2⅛	3	12	3⅜	4¾
2¼	3¼	14	3⅝	5⅛
2⅜	3⅜	16	3⅞	5½
	3⅝	18		5⅞
	3⅞	20		6⅛
	4	22		6½
	4¼	24		6¾

45.

SUM OF DIAMETERS OF KNOTS ON ANY FACE, CENTER HALF OF LENGTH, NOT TO EXCEED

Dense Select and Select	Dense Common and Common
Width of face	One and one-half times width of face

46.

SHAKES AND CHECKS

Dense Select and Select		Dense Common and Commnn
One-fourth width of end..... ...	Green	Four-tenth width of end
One-third width of end.....	Seasoned	Four-ninth width of end

47.

SLOPE OF GRAIN, CENTER HALF OF LENGTH

Dense Select and Select	Dense Common and Common
1 in 15.....	1 in 10

48.

WANE

Dense Select and Select	Dense Common and Common
One-eighth width of any face.....	One-fourth width of any face

49. Douglas fir or Southern pine of dense grades shall be selected for ensity. Douglas fir of select grade shall be selected for close grain.

VII. POSTS AND TIMBERS

Posts, Caps, Sills, Other Timbers, Etc.

50. Nominal sizes: 6 × 6 in. and larger.
Standard lengths: Multiples of 2 ft.
S1S, S1E, S2S, or S4S; ½ in. off each way.

51.

KNOTS[1]

Dense Select and Select, inches	Width of face, inches	Dense Common and Common, inches
1½	6	2⅜
2	8	3⅛
2½	10	4
3	12	4¾
3¼	14	5⅛
3⅜	16	5½
3⅝	18	5⅞
3⅞	20	6⅛
4	22	6½
4¼	24	6¾

[1] On faces less than 6 in., knots shall not exceed:

In dense select and select.....	One-fourth width of face
In dense common and common.....	Four-tenths width of face

52.

SUM OF DIAMETERS OF ALL KNOTS WITHIN ANY 6 IN. OF LENGTH, NOT TO EXCEED

Dense Select and Select	Dense Common and Common

Twice size of maximum knot allowable; not to be two of maximum allowable knots in same 6 in. of length on any one face.

53.

SHAKES AND CHECKS

Dense Select and Select		Dense Common and Common
Four-tenths width of end.....	Green	One-half width of end
One-half width of end.....	Seasoned	Six-tenths width of end

54.

SLOPE OF GRAIN

Dense Select and Select	Dense Common and Common
1 in 10.....	1 in 8

55.

WANE

Dense Select and Select	Dense Common and Common
One-eighth width of any face.....	One-fourth width of any face

56. Douglas fir or southern pine of dense grades shall be selected for density. Douglas fir of select grade shall be selected for close grain.

Working Stresses for Joist and Plank and Beams and Stringers

Continuously Dry

(Pounds per square inch)

Recommended by Forest Products Laboratory, United States Forest Service, for Grades Complying with the Minimum Basic Structural Provisions of American Lumber Standards

Species	American Standard grade	Extreme fiber in bending	Maximum horizontal shear	Compression perpendicular to grain	Modulus of elasticity
Cedar:					
Alaska	Select	1,100	90	250	1,200,000
	Common	880	72		
Northern and southern white	Select	750	70	175	800,000
	Common	600	56		
Port Orford	Select	1,100	90	250	1,200,000
	Common	880	72		
Western red	Select	900	80	200	1,000,000
	Common	720	64		
Cypress:					
Southern	Select	1,300	100	350	1,200,000
	Common	1,040	80		
Douglas fir:					
Coast type[1]	Dense select	1,750	105	380	1,600,000
	Select	1,600	90	345	
	Dense common	1,400	103	380	
	Common	1,200	72	325	
Rocky Mountain type	Select	1,100	85	275	1,200,000
	Common	880	68		
Fir:					
Balsam	Select	900	70	150	1,000,000
	Common	720	56		
Golden, noble, silver, white	Select	1,100	70	300	1,100,000
	Common	880	56		
Hemlock:					
Eastern	Select	1,100	70	300	1,100,000
	Common	880	56		
West Coast	Select	1,300	75	300	1,400,000
	Common	1,040	60		
Larch:					
Western	Select	1,200	100	325	1,300,000
	Common	960	80		
Pine:					
California, Idaho and northern white, Pondosa, and sugar	Select	900	85	250	1,000,000
	Common	720	68		
Norway	Select	1,100	85	300	1,200,000
	Common	880	68		
Southern yellow[2]	Dense select	1,750	128	380	1,600,000
	Dense common	1,400	103	380	
	Common	1,200	88	325	
Redwood	Select	1,200	70	250	1,200,000
	Common	960	56		
Spruce:					
Engelmann	Select	750	70	175	800,000
	Common	600	56		
Red, white, and Sitka	Select	1,100	85	250	1,200,000
	Common	880	68		
Tamarack	Select	1,200	95	300	1,300,000
	Common	960	76		

[1] See p. 114, paragraph 2.
[2] See p. 114, paragraph 1.

Working Stresses for Joist and Plank and Beams and Stringers

Occasionally Wet but Quickly Dried

(Pounds per square inch)

Recommended by Forest Products Laboratory, United States Forest Service, for Grades Complying with the Minimum Basic Structural Provisions of American Lumber Standards

Species	American Standard grade	Extreme fiber in bending: 4 in. and thinner	Extreme fiber in bending: 5 in. and thicker	Maximum horizontal shear	Compression perpendicular to grain	Modulus of elasticity
Cedar:						
Alaska	Select	890		90	200	1,200,000
	Common	760		72		
Northern and southern white	Select	580		70	140	800,000
	Common	490		56		
Port Orford	Select	890	1,000	90	200	1,200,000
	Common	760	800	72		
Western red	Select	710	800	80	150	1,000,000
	Common	600	640	64		
Cypress:						
Southern	Select	980		100	250	1,200,000
	Common	830		80		
Douglas fir:						
Coast type[1]	Dense select	1,370	1,515	105	265	1,600,000
	Select	1,240	1,385	90	240	
	Dense common	1,145	1,210	84	265	
	Common	980	1,040	72	225	
Rocky Mountain type	Select	800	900	85	225	1,200,000
	Common	680	720	68		
Fir:						
Balsam	Select	670		70	125	1,000,000
	Common	570		56		
Golden, noble, silver, white	Select	800		70	225	1,100,000
	Common	680		56		
Hemlock:						
Eastern	Select	800		70	225	1,100,000
	Common	680		56		
West Coast	Select	980	1,100	75	225	1,400,000
	Common	830	880	60		
Larch:						
Western	Select	980	1,100	100	225	1,300,000
	Common	830	880	80		
Pine:						
California, Idaho and northern white, Pondosa, and sugar	Select	710		85	150	1,000,000
	Common	600		68		
Norway	Select	890		85	175	1,200,000
	Common	760		68		
Southern yellow[2]	Dense select	1,370	1,515	128	265	1,600,000
	Dense common	1,145	1,210	103	265	
	Common	980	1,040	88	225	
Redwood	Select	890	1,000	70	150	1,200,000
	Common	760	800	56		
Spruce:						
Engelmann	Select	580		70	140	800,000
	Common	490		56		
Red, white, and Sitka	Select	800	900	85	150	1,200,000
	Common	680	720	68		
Tamarack	Select	980		95	225	1,300,000
	Common	830		76		

[1] See p. 114, paragraph 2.
[2] See p. 114, paragraph 1.

Working Stresses for Joist and Plank and Beams and Stringers

More or Less Continuously Damp or Wet

(Pounds per square inch)

Recommended by Forest Products Laboratory, United States Forest Service, for Grades Complying with the Minimum Basic Structural Provisions of American Lumber Standards

Species	American Standard grade	Extreme fiber in bending		Maximum horizontal shear	Compression perpendicular to grain	Modulus of elasticity
		4 in. and thinner	5 in. and thicker			
Cedar:						
Alaska	Select	800		90	150	1,200,000
	Common	680		72		
Northern and southern white	Select	530		70	100	800,000
	Common	450		56		
Port Orford	Select	800	900	90	150	1,200,000
	Common	680	720	72		
Western red	Select	670	750	80	125	1,000,000
	Common	570	600	64		
Cypress:						
Southern	Select	800		100	225	1,200,000
	Common	680		80		
Douglas fir:						
Coast type[1]	Dense select	1,050	1,165	105	235	1,600,000
	Select	950	1,065	90	215	
	Dense common	875	930	84	235	
	Common	750	800	72	200	
Rocky Mountain type	Select	620	700	85	200	1,200,000
	Common	530	560	68		
Fir:						
Balsam	Select	530		70	100	1,000,000
	Common	450		56		
Golden, noble, silver, white	Select	710		70	200	1,100,000
	Common	600		56		
Hemlock:						
Eastern	Select	710		70	200	1,100,000
	Common	600		56		
West Coast	Select	800	900	75	200	1,400,000
	Common	680	720	60		
Larch:						
Western	Select	800	900	100	200	1,300,000
	Common	680	720	80		
Pine:						
California, Idaho and northern white, Pondosa, and sugar	Select	670		85	125	1,000,000
	Common	570		68		
Norway	Select	710		85	150	1,200,000
	Common	600		68		
Southern yellow[2]	Dense select	1,050	1,165	128	235	1,600,000
	Dense common	875	930	103	235	
	Common	750	800	88	200	
Redwood	Select	710	800	70	125	1,200,000
	Common	600	640	56		
Spruce:						
Engelmann	Select	440		70	100	800,000
	Common	370		56		
Red, white, and Sitka	Select	710	800	85	125	1,200,000
	Common	600	640	68		
Tamarack	Select	800		95	200	1,300,000
	Common	680		76		

[1] See p. 114, paragraph 2.
[2] See p. 114, paragraph 1.

Working Stresses for Posts and Timbers 6 by 6 In. and Larger

Continuously Dry

(Pounds per square inch)

Recommended by Forest Products Laboratory, United States Forest Service, for Grades Complying with the Minimum Basic Structural Provisions of American Lumber Standards

Compression Parallel to Grain

Ratio of Length to Least Dimension (L/D)

Species	American Standard grade	10	12	14	16	18	20	25	30	35	40	50	Modulus of elasticity
Cedar:													
Alaska	Select	793	786	774	753	726	688	526	365	268	206	132	1,200,000
	Common	636	632	627	617	602	582	500					
Northern and southern white	Select	545	540	530	516	496	468	351	244	179	137	88	800,000
	Common	437	435	430	423	412	398	338					
Port Orford	Select	890	879	861	834	796	741	526	365	268	206	132	1,200,000
	Common	715	709	700	686	667	639	521					
Western red	Select	693	686	674	656	629	592	438	304	224	171	110	1,100,000
	Common	557	553	547	538	524	505	425					
Cypress:													
Southern	Select	1,082	1,063	1,030	981	909	810	526	365	268	206	132	1,200,000
	Common	870	861	843	818	781	729						
Douglas fir:													
Coast type[1]	Dense select	1,268	1,250	1,221	1,177	1,113	1,024	702	487	358	274	175	1,600,000
	Select	1,162	1,149	1,127	1,093	1,045	975	702					
	Dense common	1,025	1,017	996	965	935	893	698					
	Common	876	870	861	847	826	796	675					
Rocky Mountain type	Select	793	786	774	753	726	688	526	365	268	206	132	1,200,000
	Common	636	632	627	617	602	582	500					

Fir:													
Balsam	Select	693	686	674	656	629	592	438	304	224	171	110	1,000,000
	Common	557	553	547	538	524	505	425					
Commercial white	Select	694	689	678	664	641	611	482	335	246	188	121	1,100,000
	Common	557	554	549	542	530	515	449					
Hemlock													
Eastern	Select	694	689	678	664	641	611	482	335	246	188	121	1,100,000
	Common	557	554	549	542	530	515	449					
West Coast	Select	893	885	872	852	823	783	614	426	313	240	153	1,400,000
	Common	716	712	706	696	680	660	573					
Larch:													
Western	Select	1,085	1,068	1,041	999	937	851	570	396	291	223	142	1,300,000
	Common	872	863	849	828	798	752						
Pine:													
California, Idaho and northern white, Pondosa, and sugar	Select	742	733	718	695	663	617	438	304	224	171	110	1,100,000
	Common	596	591	583	572	556	532	434					
Norway	Select	793	786	774	753	726	688	526	365	268	206	132	1,200,000
	Common	636	632	627	617	602	582	500					
Southern yellow[2]	Dense select	1,268	1,250	1,221	1,177	1,113	1,024	702	487	358	274	175	1,600,000
	Dense common	1,025	1,017	996	965	935	893	698					
	Common	876	870	861	847	826	796	675					
Redwood	Select	986	972	947	910	856	781	526	365	268	206	132	1,200,000
	Common	793	786	773	754	726	688						
Spruce:													
Engelmann	Select	594	586	574	556	530	494	351	244	179	137	88	800,000
	Common	476	473	466	457	444	426	347					
Red, white, and Sitka	Select	793	786	774	753	726	688	526	365	268	206	132	1,200,000
	Common	636	632	627	617	602	582	500					
Tamarack	Select	988	976	955	923	877	817	570	396	291	223	142	1,300,000
	Common	794	788	777	761	737	706	566					

[1] See p. 114, paragraph 2.
[2] See p. 114, paragraph 1.

Working Stresses for Posts and Timbers 6 by 6 In. and Larger

Occasionally Wet but Quickly Dried

(Pounds per square inch)

Recommended by Forest Products Laboratory, United States Forest Service, for Grades Complying with the Minimum Basic Structural Provisions of American Lumber Standards

Compression Parallel to Grain

Ratio of Length to Least Dimension (L/D)

Species	American Standard grade	10	12	14	16	18	20	25	30	35	40	50	Modulus of elasticity
Cedar:													
Alaska	Select	744	738	728	712	689	657	523	365	268	206	132	1,200,000
	Common	597	594	588	581	569	552	485					
Northern and southern white	Select	496	492	485	474	459	438	348	244	179	137	88	800,000
	Common	398	396	392	387	379	368	323					
Port Orford	Select	818	808	795	774	744	702	526	365	268	206	132	1,200,000
	Common	656	652	645	634	618	597	506					
Western red	Select	693	686	674	656	629	592	438	304	224	171	110	1,000,000
	Common	557	553	547	538	524	505	425					
Cypress:													
Southern	Select	986	972	947	910	856	781	526	365	268	206	132	1,200,000
	Common	793	786	773	754	726	688						
Douglas fir:													
Coast type[1]	Dense select	1,153	1,139	1,118	1,086	1,038	972	701	487	358	274	175	1,600,000
	Select	1,055	1,045	1,029	1,004	968	917	701					
	Dense common	935	924	905	886	858	830	681					
	Common	796	792	785	774	758	737	646					
Rocky Mountain type	Select	793	786	774	753	726	688	526	365	268	206	132	1,200,000
	Common	636	632	627	617	602	582	500					

Fir:													
Balsam	Select	596	591	583	572	556	532	434	304	224	171	110	1,000,000
	Common	478	476	472	466	457	445	395					
Commercial white	Select	694	689	678	664	641	611	482	335	246	188	121	1,100,000
	Common	557	554	549	542	530	515	449					
Hemlock:													
Eastern	Select	694	689	678	664	641	611	482	335	246	188	121	1,100,000
	Common	557	554	549	542	530	515	449					
West Coast	Select	893	885	872	852	823	783	614	426	313	240	153	1,400,000
	Common	716	712	706	696	680	660	573					
Larch:													
Western	Select	988	976	955	923	877	813	570	396	291	223	142	1,300,000
	Common	794	788	777	761	737	706	566					
Pine:													
California, Idaho and northern white, Pondosa, and sugar	Select	742	733	718	695	663	617	438	304	224	171	110	1,000,000
	Common	596	591	583	572	556	532	434					
Norway	Select	793	786	774	753	726	688	526	365	268	206	132	1,200,000
	Common	636	632	627	617	602	582	500					
Southern yellow[2]	Dense select	1,153	1,139	1,118	1,086	1,038	972	701	487	358	274	175	1,600,000
	Dense common	935	924	905	886	858	830	681					
	Common	796	792	785	774	758	737	646					
Redwood	Select	890	879	861	834	796	741	526	365	268	206	132	1,200,000
	Common	715	709	700	686	667	639	521					
Spruce:													
Engelmann	Select	545	540	530	516	496	468	351	244	179	137	88	800,000
	Common	437	435	430	423	412	398	338					
Red, white, and Sitka	Select	744	738	728	712	689	675	523	365	268	206	132	1,200,000
	Common	597	594	588	581	569	552	485					
Tamarack	Select	892	882	868	844	811	765	570	396	291	223	142	1,300,000
	Common	716	711	703	691	674	650	548					

[1] See p. 114, paragraph 2.
[2] See p. 114, paragraph 1.

Working Stresses for Posts and Timbers 6 by 6 In. and Larger

More or Less Continuously Damp or Wet

(Pounds per square inch)

Recommended by Forest products Laboratory, United States Forest Service, for Grades Complying with the Minimum Basic Structural Provisions of American Lumber Standards

Compression Parallel to Grain

Ratio of Length to Least Dimension (L/D)

Species	American Standard grade	10	12	14	16	18	20	25	30	35	40	50	Modulus of elasticity
Cedar:													
Alaska	Select	646	642	636	625	611	590	504	365	268	206	132	1,200,000
	Common	518	516	513	507	500	489	444	364				
Northern and southern white	Select	447	444	439	432	420	405	340	244	179	137	88	800,000
	Common	358	357	354	351	345	337	304	243				
Port Orford	Select	744	738	728	712	689	657	523	365	268	206	132	1,200,000
	Common	597	594	588	581	569	552	485					
Western red	Select	645	639	629	614	593	564	439	304	224	171	110	1,000,000
	Common	517	514	510	502	491	476	412					
Cypress:													
Southern	Select	793	786	774	753	726	688	526	365	268	206	132	1,200,000
	Common	636	632	627	617	602	582	500					
Douglas fir:													
Coast type[1]	Dense select	982	974	961	942	912	871	699	487	358	274	175	1,600,000
	Select	899	893	883	868	845	814	683	487				
	Dense common	795	785	777	767	753	730	642	482				
	Common	677	675	670	664	655	641	586	484				
Rocky Mountain type	Select	695	690	682	669	651	625	518	365	268	206	132	1,200,000
	Common	558	555	551	544	535	521	466					

Fir:													
Balsam	Select	498	495	490	484	474	460	404	304	224	171	110	1,000,000
	Common	399	397	395	392	387	380	351	298				
Commercial white	Select	596	593	587	577	563	544	463	335	246	188	121	1,100,000
	Common	478	476	473	468	461	451	409	334				
Hemlock:													
Eastern	Select	596	593	587	577	563	544	463	335	246	188	121	1,100,000
	Common	478	476	473	468	461	451	409	334				
West Coast	Select	795	790	780	766	746	718	598	426	313	240	153	1,400,000
	Common	637	634	630	623	612	598	537					
Larch:													
Western	Select	794	788	777	761	737	706	566	396	291	223	142	1,300,000
	Common	637	634	628	620	608	591	520					
Pine:													
California, Idaho and northern white, Pondosa, and sugar	Select	645	639	629	614	593	564	439	304	224	171	110	1,000,000
	Common	517	514	510	502	491	476	412					
Norway	Select	695	690	682	669	651	625	518	365	268	206	132	1,200,000
	Common	558	555	551	544	535	521	466					
Southern yellow[2]	Dense select	982	974	961	942	912	871	699	487	358	274	175	1,600,000
	Dense common	795	785	777	767	753	730	642	482				
	Common	677	675	670	664	655	641	586	484				
Redwood	Select	744	738	728	712	689	657	523	365	268	206	132	1,200,000
	Common	597	594	588	581	569	552	485					
Spruce:													
Engelmann	Select	447	444	439	432	420	405	340	24[illegible]	179	137	88	800,000
	Common	358	357	354	351	345	337	304	243				
Red, white, and Sitka	Select	646	642	636	625	611	590	504	365	268	206	132	1,200,000
	Common	518	516	513	507	500	489	444	364				
Tamarack	Select	794	788	777	761	737	706	566	396	291	223	142	1,300,000
	Common	637	634	628	620	608	591	520					

[1] See p. 114, paragraph 2.

[2] See p. 114, paragraph 1.

NOTES ON WORKING STRESSES

The working stresses in all the tables in this chapter are recommended by the Forest Products Laboratory, United States Forest Service, for structural grades complying with the minimum Basic Provisions for Structural Material of American Lumber Standards. In *beam and stringer*, and *post and timber* grades, stresses are given only for the species commonly cut to these sizes. Stresses for any other species can be obtained from the Forest Products Laboratory, Madison, Wisconsin.

Structural grades are developed to insure minimum strength values. The defects permitted in the common grades provide material having not less than 60 per cent of the strength of green, clear wood, and in the select grades, 75 per cent, although in Douglas fir the stresses recommended in compression and in extreme fiber in bending are 80 per cent of green, clear wood strength on account of the limitation on rate of growth.

Working values are given for three conditions of exposure during use: (*a*) continuously dry; (*b*) occasionally wet but quickly dried; (*c*) more or less continuously damp or wet. Judgment should be exercised as to the values to be used in a particular case.

a. Continuously dry contemplates use in interior or protected construction, not subject to conditions of excessive dampness or high humidity.

b. Occasionally wet but quickly dried assumes use in such exterior structures as bridges, trestles, grand stands or bleachers, and exposed framework of open sheds.

c. More or less continuously damp or wet would apply to material exposed to waves or tidewater, or in contact with earth, or used in a building in portions that would be more or less continuously wet.

The working values recommended may be used without allowance for impact up to 100 per cent.

Horizontal Shear

Working values given for horizontal shear are maximum values. The maximum unit horizontal shear at any point in a beam is three-halves of the average unit shear obtained by dividing the total shear at that point by the area of the cross-section. To get the total safe shearing strength at any cross-section, the area of the cross-section should be multiplied by two-thirds the maximum allowable horizontal shear. To obtain the required area to carry any given shear, the total shear should be divided by two-thirds the maximum allowable unit shear.

Recognition of all loads in designing for loads concentrated near a support, or for moving loads, gives a calculated shearing stress higher than is actually developed. In calculating the shear at one end of a

beam, the concentrated loads between that end and the nearer quarter point, or between that end and a point distant three times the depth of the beam from it, whichever would be the lesser distance from the support, may be considered as acting at that point. For moving loads, as on highway bridges or railway stringers, in computing the shear at one end it is safe to ignore all wheel loads between that end and the nearer quarter point, or between that end and a point three times the depth of the beam or stringer from it, whichever would be the lesser distance from the support, when the balance of the span is assumed to be loaded so as to give a maximum shear stress.

Shear stresses for joint details may be taken as 50 per cent greater than the values for horizontal shear given in the table.

Timber constantly yields under continued loading, acquiring a permanent set. This set with a fully loaded beam is about equal to the deflection using the modulus of elasticity as given in the tables. In order to minimize the results of sag, it is advisable to use values one-half those given in the tables.

Compression Parallel to Grain

The working stresses for compression parallel to grain are for use on posts, struts, etc., with unsupported length not greater than ten times their least dimension. They are also for use in end bearing on compression members, as a short column or strut is more likely to fail at the end than at any other point in its length, and the variations in moisture content are greater there.

For columns of intermediate length, the Forest Products Laboratory finds from tests recently made that a fourth-power parabola, tangent to the Euler curve, is a conservative representation of the law controlling the strength. That is, from the short block to the long column in which the strength is dependent on stiffness, there is a falling off in ultimate strength which follows a smooth curve, very flat at first but curving sharply to become tangent to the Euler curve at two-thirds of the ultimate crushing strength.

For columns from $\frac{P}{A} = S$ to $\frac{P}{A} = \frac{2}{3}S$.

$$\frac{P}{A} = S\left[1 - \frac{1}{3}\left\{\frac{l}{Kd}\right\}^4\right]$$

where P = total load in pounds.
A = area in square inches.
$\frac{P}{A}$ = unit compressive stress.
S = safe stress in compression parallel to grain.
l = unsupported length in inches.
d = least dimension in inches.

E = modulus of elasticity.

K = the $\frac{l}{d}$ at the point of tangency of parabolic and Euler curves, when $\frac{P}{A} = \frac{2}{3}S$. The value of K for any species and grade is $\frac{\pi}{2}\sqrt{\frac{E}{6S}}$.

The influence of defects on the compressive strength of columns of constant cross-section decreases as the length increases. When $\frac{l}{d}$ equals the value of K for the species and grade, defects such as are allowable in the grade have little influence on the strength as a column. Beyond this length the investigation of the strength of columns indicated that the Euler formula is quite accurate for long wood columns with pin-end connections and that the maximum load is dependent upon stiffness. In such columns a factor of safety of 3 should be applied to values of modulus of elasticity in order to obtain safe loading.

The laboratory does not, with the present data and under ordinary conditions, find justification for increasing the stresses on square-end columns over those for carefully centered pin-end columns. Tests to determine the influence of end conditions are still being made, and it is probable that under special conditions higher stresses can be used.

For long columns, including factor of safety of 3:

$$\frac{P}{A} = \frac{\pi^2 E}{36\left(\frac{l}{d}\right)^2}$$

Columns should be limited in slenderness to $\frac{l}{d} = 50$.

Post and timber grades may be applied to material smaller than 6 by 6 in. by limiting the size of knots to the proportion of width of face permitted on a 6-in. face.

Direct Tension

For direct tension the same values as for extreme fiber stress in bending may be used. Straight-grained wood has greater resistance to tension than to any other kind of stress. It has been found practically impossible, however, to design joints that will develop anywhere nearly the full tensile strength.

Grades of joists or beams may be used for members in direct tension, as in bottom chords of trusses, increase in size of defects toward ends being permissible because of the gradual application of stresses through splice plates or end connections.

Bending Strength

The provisions of the *joist and plank* grades are such that material graded on them may be used on edge, as joist or rafters, or flat, as scaffold plank or factory flooring, and working stresses for these grades may be applied to such material used with wide faces either vertical or horizontal. *Joist and plank* grades apply to material not thicker than 4 in. Material thicker than 4 in., for use in bending should be graded on *beam and stringer* grades. In such material with loads applied to the wide face, the knot requirements for this face are those for the narrow face as given in the rules.

Material to be used for such purposes as caps, bridge ties, etc., where strength in bending is a factor, should be specified in *beam and stringer* grades, as the method of measuring knots in *post and timber* grades makes it impracticable to assign bending stresses to them. Caps and bridge ties are often square or have horizontal faces wider than the vertical faces, in contrast to beams and stringers, in which the narrow faces are horizontal faces and the wide faces are vertical, and care should be exercised that knot limitations are applied to the proper faces.

In material subject to varying bending moments, such as full-length sills of wood underframed cars, defects throughout the length should be limited as in the center third of *beams and stringers.*

In railway stringers of two-span length, defects throughout the center two-thirds should be limited as in the center third of a single span stringer, for the maximum moment will be over the center support, and although the full positive moment would not be developed in either span so long as there was resistance to negative moment over the center support, there might be circumstances in which full positive moment of resistance at the centers of the two spans would be desirable.

FACTORS OF SAFETY

Safe working stresses are obtained by applying a factor to observed authentic laboratory test values. This factor is generally known as a *factor of safety* and has also been termed a *factor of ignorance.* In the past, when a flat factor of 10 was often applied to all properties and all species of wood, the latter term was the more accurate, for the greater portion of the factor was to care for the unknown effect of the many variables which affect the strength of wood. Today, neither term applies, since the factor is applied to test values and relates only to the known variability of clear wood, the influence of defects, moisture, and duration of stress. Only a small portion of the factor is to care for possible overload or to apply as a factor of safety.

Assuming that timber is to be used with a working stress of 1,600 lb. per square inch, the corresponding strength of the material under test

should be preferably about 5,700 lb. per square inch and in no case below 4,700 lb. per square inch. This relation is deduced as follows:

Wood and Steel

It is considered good practice in steel to make the working stress one-half the fiber stress at the elastic limit. On this basis the fiber stress at the elastic limit in wood corresponding to a working stress of 1,600 lb. per square inch would be 3,200 lb. per square inch. The ratio of fiber stress at the elastic limit to the modulus of rupture or breaking stress in wood, is 9 to 16. This brings the breaking stress corresponding to a 1,600-lb. working stress to $3,200 \times 1\frac{6}{9} = 5,700$ lb. per square inch.

The so-called *factor of safety* in wood based on fiber stress at the elastic limit should not in any case fall below $1\frac{2}{3}$, as it has been shown by tests that a dead load causing a fiber stress equal to the stress at the elastic limit has ultimately produced failure. In the same way that the breaking stress corresponding to the factor of 2 is 5,700 lb. per square inch, so the breaking stress corresponding to a factor of $1\frac{2}{3}$ is approximately 4,700 lb. per square inch. On this basis, any rule for selecting timber to be used with a working stress of 1,600 lb. per square inch should give material with a breaking stress in the large majority of cases (75 per cent) above 5,700 lb. per square inch, with comparatively few pieces (25 per cent) between 5,700 and 4,700 lb. per square inch, and with no pieces having a breaking stress less than 4,700 lb. per square inch.

Unfortunately, the term *factor of safety* has been rather generally applied by engineers and laymen to the total factor used in obtaining working stresses from test values. It has often been assumed that when so applied it indicated the overload which a structural member would carry. Such an assumption is a serious error, as it may lead to failure from overloading. In this discussion, the term *factor of safety* applies only to the overload factor and does not include that portion of total factor which takes care of the adjustment for known variables.

Elastic Limit and Breaking Strength

In determining working stresses, the Forest Products Laboratory has considered both elastic limit and breaking strength. Elastic limit is more variable and less definite than ultimate strength, and the latter is taken as the more dependable basis for determination of safe working stress.

The factor of safety at a given stress varies materially with the duration of the stress. At the recommended working stresses, the average timber in buildings has a factor of safety of 6 on impact loading,[1] 4 under 5-min. loads, and $2\frac{1}{4}$ under long-time loading, with a minimum factor of

[1] If impact stresses are neglected when less than 100 per cent of the live load producing them, the factor of safety for such loads would be reduced from 6 to a minimum of 3.

safety of two on 75 per cent of the pieces under long-time loading, while about one piece in one hundred, of very light weight and with maximum defects for the grade, would be expected to break at one and one-half times the recommended stress under loading of approximately 10 years' duration. The factor of safety on new timbers in bridge work is about one-seventh greater than the above values.

FACTORS AFFECTING WORKING STRESSES

Working stresses are based on the strength of the clear wood of the various species and, in some properties, on grade as fixed by limitation on size and location of knots, extent of shake and checks, and extent of cross-grain, on conditions of exposure during use, and on size of piece. In southern pine and Douglas fir, working stresses in some properties are increased for requirement of percentage of summerwood, and in Douglas fir, for limitation on rate of growth.

Workings stresses for extreme fiber in bending are varied with grade, extent of exposure, and size of piece; in horizontal shear, they are varied with grade; in compression parallel to grain, with grade and exposure; in compression perpendicular to grain, with exposure.

Working stresses in shear are not varied with size or extent of exposure; in compression parallel to grain they are not varied with size; in compression perpendicular to grain they are not varied with grade or size; in modulus of elasticity they are taken as the same in all grades.

In southern pine and Douglas fir, working stresses in extreme fiber in bending, horizontal shear, compression parallel to grain, and compression perpendicular to grain may be increased one-sixth for dense material, over material not so selected. Values in Douglas fir may be increased one-fifteenth for close grain in extreme fiber in bending, compression parallel to grain, and compression perpendicular to grain. Values in horizontal shear are not increased for close grain. Modulus of elasticity is not varied with density or rate of growth.

VARIATIONS IN WORKING STRESSES

(x, varies with: —, does not vary with)

Property	Governing defects	Conditions of exposure	Grade	Size of piece	Rate of growth	Density
Extreme fiber in bending	Knots and slope of grain	x	x	x[1]	x	x
Horizontal shear	Shake and checks	—	x	—	—	x
Compression parallel	Knots and slope of grain	x	x	—	x	x
Compression perpendicular	.....	x	—	—	x	x
Modulus of elasticity	.....	—	—	—	—	—

[1] Dry location only.

COMMERCIAL GRADING RULES FOR STRUCTURAL MATERIAL

Thus far, two regional lumber manufacturers' associations have developed and published grading rules for structual material to which working stresses have been assigned. Others have announced their intention of doing so.

1. The Southern Pine Association has published four structural grades, namely, *select structural, dense heart, structural square edge and sound,* and *No.* 1 *common,* and has assigned working stresses to these grades. They are published in "Standard Specifications for Grades of Dense Longleaf and Shortleaf Southern Yellow Pine Structural Timbers, Joist and Plank, and Utility Timbers," dated Mar. 23, 1927, with supplement dated July 1, 1928.

2. The West Coast Lumbermen's Association has published three structural grades for Douglas Fir—*dense structural, structural,* and *No.* 1 *common* (with slope of grain limited to 1 in 10), to which it has assigned the working stresses recommended by the Forest Products Laboratory and previously shown for the basic grades of dense select, select, and common structural, respectively. These grades are published in the "Standard Grading and Dressing Rules for Douglas Fir, Sitka Spruce, West Coast Hemlock, and Western Red Cedar Lumber," under date of July 1, 1926.

Structural material of southern pine and Douglas fir is manufactured and sold on commercial grades incorporated in the grading rules of the Southern Pine Association and the West Coast Lumbermen's Association, respectively. Users should, in their purchase orders, specify the commercial grades provided in the association standard grading rules.

References

California Redwood Association	San Francisco, Cal.
California White and Sugar Pine Manufacturers Association	San Francisco, Cal.
Hardwood Manufacturers Institute	Memphis, Tenn.
National Hardwood Lumber Association	Chicago, Ill.
North Carolina Pine Association	Norfolk, Va., and Macon, Ga.
Northern Pine Manufacturers Association	Minneapolis, Minn.
Northern Hemlock and Hardwood Manufacturers Association	Oshkosh, Wis.
Southern Cypress Manufacturers Association	Jacksonville, Fla.
Southern Pine Association	New Orleans, La.
West Coast Lumbermen's Association	Seattle, Wash., and Portland, Ore.
Western Pine Manufacturers Association	Portland, Ore.

CHAPTER III

PRINCIPAL WOODS USED IN BUILDING AND CONSTRUCTION

The enumeration of the principal woods used in building and construction, contained in the following paragraphs, is intended to give information of practical value on the properties of the various species and to point out the uses to which each wood is most commonly applied. Judgment is needed to select proper species for particular uses, but judgment cannot be better than the information upon which it is based. Therefore an effort is made to give reliable, authentic information, based upon the experience of those who use wood in construction. The forest region in which each species grows is described, and the peculiar characteristics inherent in a species which affect its use in construction are discussed. Strength, durability, receptivity to paint or stain, and other distinguishing qualities are also outlined. Average weights for the various important commercial woods are given in the table on page 599 of the appendix.

SOUTHERN PINE

The collective term *southern yellow pine* or *southern pine* is widely and favorably known to the interior markets, but in the export markets it is known as *pitch pine*. This wood has a multiplicity of uses which give it a wide distribution. The heavy annual production of southern pine makes for economy, ready purchase, and consumption in the United States, from the Rocky Mountains eastward. Botanically, there are several different species, principal among them being longleaf, shortleaf, loblolly, slash (Cuban), and pond pine. These woods grow in all of the Southern states, from Virginia to Texas. As there are no extremes of temperature in most of these states, the growth of southern pine is a rapid, natural one. Sunlight, or the lack of it, does more to determine growth than almost any other factor. Generally, and especially in the virgin forests, the trees grow very straight and attain an average height of about 75 feet. This is of particular importance to lumbermen, as such trees are comparatively free from knots, except near the top.

While there is no way to distinguish between longleaf and shortleaf pine except by the size of the pith, the terms have come to be associated with definite qualities. *Longleaf pine* is heavy and close ringed, and the term is used commercially to designate any of the southern pines having a large percentage of dark wood or summerwood, while the soft-textured light-weight wood is commonly known as *shortleaf pine*, regardless of the

species. These trade names, while not defining the species botanically, have been found a convenient basis for commercial classification. It is true that the same range in strength values may be found in both species, but in longleaf pine about 65 per cent will qualify as dense under the grading-rule provisions and is of exceptionally dense quality, with only a small percentage falling in the lower half of the density range. It is this uniformity in tree growth that has made the term *longleaf* synonymous with structural value, and its use by the specifying public has come to indicate a definite quality of lumber.

Among the southern pines there are no fundamental differences which make all of the wood of one species preferable to all of the wood of another, for any given purpose. The dense wood of any southern pine has practically the same strength and other characteristics as the dense wood of any other southern pine, and the lighter-weight pieces are more or less alike. Low-density pine is not necessarily inferior. In fact, in some respects and for some uses, it is superior to dense material. It weighs less and, therefore, entails less cost in handling and shipment; it warps and checks less; it works more easily, splits less in nailing, often holds paint better; and it is a better insulator of heat than heavier material.

The southern pines have overlapping ranges in density and quality of material and consequently overlap one another in their uses. Many consumers ordering southern-pine lumber make no distinction as to species. Some use the term *longleaf* or simply *southern pine* when they desire dense material and *shortleaf*, *Arkansas soft pine*, or *North Carolina pine* when they want lighter material. Others in specifying *longleaf* refer to the definite species which bears that name. Confusion and litigation sometimes result because the buyer and seller do not understand each other's terminology.

The application of the density rule enables the consumer desiring dense lumber for a specific use to obtain it easily by specifying on his order the quality wanted. An application of the density rule in judging lumber quality provides a means of getting the highest type of construction lumber.

Virgin-growth southern pine is denser on the average than second-growth pine. As high as 90 per cent of the longleaf and slash pines cut from a virgin stand would be classified as dense under the grading rules. The percentage of virgin-growth shortleaf, loblolly, and pond pines that could actually be classified as dense is much smaller than 90 per cent. Many of the mills operating in the old lumbering regions have cut most of their virgin-timber stands and are now operating on second-growth stands.

The southern-pine region is roughly divided into two belts: the southern belt—extending about as far north as the northern boundary of Louisiana, including the coastal halves of the Carolinas and producing

mostly longleaf and slash pines—and the northern belt—extending from Arkansas across northern Mississippi, Alabama, Georgia, South Carolina, North Carolina, and Virginia, and producing chiefly shortleaf and loblolly pine. Mills operating in some localities in the southern half are now cutting timber which runs 90 to 100 per cent virgin longleaf pine, so that most of the lumber obtained from such regions is excellent for construction purposes where high density is desirable. On the other hand, many mills in the northern belt are cutting practically no longleaf or slash pines, and the shortleaf from this region is chiefly of the easy-working, smooth-textured wood desirable for finishing lumber. The southern pine cut in North Carolina, Virginia, South Carolina, and the northern part of Georgia is known commercially as *North Carolina pine.*

The heartwood of the southern pines is highly resistant to decay, and where conditions are such as to favor decay longleaf heart pine is widely used. Dense southern pine is probably the best known wood for such structural uses as factory buildings, bridges and trestles, piling, wharves and docks, foundation timbers, house sills, grandstands, sheet piling, board walks, and other kindred purposes. The less dense grades of southern pine are also most extensively used in light building construction, temporary construction, such as form work, and, in fact, in practically every field where wood may be considered as suitable material.

Shortleaf or non-dense southern-pine lumber is suited, on account of its appearance and paint-holding qualities, for all kinds of interior trim, especially where stained, painted, lacquered, hard-oiled or varnished surfaces are desired. This type of wood is especially desirable for crating, as it is light in weight for shipping, holds nails excellently, and is not inclined to split from nailing. For insulation, it is superior to dense lumber.

Yellow-pine shingles are used extensively in the Southern states but, on account of their heavy weight, do not find markets very far from home,

There are many uses for wood in which the ravages of insects, termites, and marine borers, and decay hazards are such that the wood must be treated. Properly treated southern pine, even under conditions favoring decay, will last a long time. The value of treated wood depends on the depth and uniformity of penetration of the preservative. Southern pine is admirably adapted to treatment because of the ease with which the sapwood absorbs the preservative. For this reason, sapwood is most generally used where treatment is necessary. Quantities of treated southern pine are used in cross-ties, piles, bridge timbers, poles and paving blocks, and for miscellaneous construction.

It is the variation in the weight or texture of wood that makes it adaptable for so many uses. Southern pine is used for a large variety of purposes today because of the ease with which material of the quality desired can be secured. In all the southern pines the weight or "density"

and the corresponding structural properties can be judged with a remarkable degree of accuracy by the annual rings on the end of a piece.

DOUGLAS FIR

West of the Great Plains, according to the United States Forest Service, is more than 50 per cent of the standing timber in the continental United States. Fully 50 per cent of all this timber, from the Rocky Mountains west, is in the Douglas-fir region of the two states, Washington and Oregon. Along the west slopes of these Pacific Coast states—between the Cascade Mountains and the ocean—stands from one-quarter to one-third of the timber in the United States.

Thornton T. Munger, silviculturist, director of the Pacific Northwest Forest Experiment Station, Portland, Oregon, a United States Forest Service undertaking, has stated in regard to this region:

> In the density of its forests, the huge size of its trees, and the luxuriance of its growth, this region is in the front rank. Broadly speaking, this is a primeval forest region. Of the 28,000,000 acres of original forest, only about 4,000,000 acres have been cut to date (Jan. 1, 1926) in connection with logging operations. . . . There can be no denying that the forests of this region are capable of reproducing themselves, after logging, in a most excellent fashion, and are doing so, except where unfavorable factors are at work.

Douglas fir, named for David Douglas, a Scotch botanist who visited the Pacific Northwest in 1825 and first segregated the species, is not a fir at all. Neither is it a pine, although the wood is known in markets throughout the world as *Oregon pine*. Similarly, Douglas fir has been called a spruce. Botanically, it is none of these but is a species which stands alone as the sole commercial representative of its genus on the American continent. Commercially, the name *Douglas fir* represents the species that is known to scientists as *Pseudotsuga taxifolia*, and 70 per cent of the timber in the Douglas-fir region is of this species. The remainder is: West Coast hemlock approximately 15 per cent; western red cedar approximately 10 per cent; Sitka spruce approximately 1.5 per cent; and small quantities of Port Orford cedar, noble fir, white fir, and other species of the true firs.

In the forest, Douglas-fir trees reach great dimensions, commonly attaining a height of more than 200 ft. and a diameter ranging from 5 to 6 ft. Logs cut from these old-growth trees permit the sawing of unusually large structural timbers, in addition to fine-grained and beautifully textured woods.

Douglas fir is one of the strongest woods, pound for pound, that has ever been tested. Heavy timbers of Douglas fir, from the common grades used for ordinary building, to select and dense select structural grades chosen for their particular strength values, are shipped to more than 40 different countries and also used in nearly every state in the Union.

Unusual strength is a characteristic of the entire Douglas-fir species, but the Douglas fir of the Pacific Northwest is the strongest of its family. Strength in the Douglas fir varies, as in other species, with summerwood content, straightness of grain, extent of knots and other defects, and special grades—as noted above—are prepared by the manufacturers to cover particular strength requirements on the part of architects, engineers and other builders. In these selected grades, those parts of carefully selected logs that contain the greatest strength are manufactured into these particular items. Much of this structural material is grade marked by the manufacturer, so that the buyer may be sure of receiving timbers of specified grade and strength.

Because of the great size of individual logs, the lumber produced from Douglas fir is used for an almost endless variety of purposes. In a large, mature tree, the wood near the center is usually somewhat reddish in color, tight knotted, suited for the inner portion of a great sound-hearted, square timber or for cutting into boards, boxing and crating, studding, joists, rafters, and plank. Farther from the center the wood is closer grained, denser, stronger and stiffer, suitable for the outer surfaces of great square timbers or for making the highest type of side-cut structural timbers. The wood in the outer portion of the log frequently is yellow in color, fine grained, moderately soft, and suitable for the manufacture of the finest grades of interior finish and woodwork, exterior siding, window sash and frames, doors, long ladder rails, airplane wingbeams, and for other exacting uses.

Smaller, younger Douglas-fir timber will be of more uniform growth and type throughout the log, usually close grained and tight knotted through the central portion and so suited for high-grade boxed-heart structural timbers or tight knotted dimension or plank. The outer portion of these smaller logs will have a smaller percentage of clear lumber than the large, old-growth log, but the clear lumber is of excellent type and quality.

One of the distinctive features of the Douglas fir is its thin layer of sapwood, averaging not more than 2 in. thick in a 48-in. log. Large structural timbers with 100 per cent heart face may be taken from an average Douglas-fir log, and it is unlikely that any considerable amount of sapwood will be left on a timber by a Douglas-fir manufacturer, because the sapwood has a greater value for clear cuttings.

Based upon rate of growth, the wood of the Douglas fir can be classified under three types: the medium-grained wood of the structural type; the coarser-grained wood of the center of the rapidly growing tree; and the fine-grained, soft, old-growth wood.

These three classifications give a variety of type in Douglas fir that is similar to that found in each species of southern pine, but it is all Douglas fir, and identification must be made by "type" names, as there are

no distinguishing names of species by which to identify the various types.

West Coast manufacturers have not in the past been accustomed to make the distinctions in Douglas-fir types that the South has long made under the designation of *longleaf* and *shortleaf* pine, and the result has been a feeling in the East that there is more variability in West Coast woods than in Southern woods. This will be overcome by segregation of type at time of manufacturing and is being done now in the case of structural timbers and by mills cutting certain industrial specifications.

Some of the largest and most modern sawmills and woodworking plants in the world today are located in the Douglas-fir region, and these depend very largely on the Douglas-fir forests for raw material. Timbers, lumber, doors, plywood, veneers, water pipe, tank stock, house-building material—from framing to the most beautiful interior finish, piling, bridge and car timbers—altogether some 2,500 items, are produced from Douglas fir in the Pacific Northwest mills and woodworking plants, or manufactured elsewhere from raw material brought from the West Coast.

The Douglas-fir lumber products originating in the northern Rocky Mountain territory are marketed under the name *red fir*. In strength properties, red fir is not quite the equal of Douglas fir from the Pacific Northwest, but it is suitable for general construction purposes and is manufactured into various items going into building construction.

NORTHERN WHITE PINE

It is said that the history of the United States was founded on white-pine lumber. It was the first species of wood to be utilized by the Pilgrims for the construction of their homes, and from that time to this it has been one of America's favorite woods in the building and construction field. The term *northern white pine* is used synonymously with eastern white pine; but in the trade it is also known as *Canadian white pine, Minnesota white pine, northern pine, soft-cork white pine, white pine, soft white pine, and Wisconsin white pine.* It is found from Maine to Minnesota and southward in the Appalachians to northern Georgia.

The wood is light in weight, and the heartwood ranges in color from white, with a pinkish cast, to gray. The sapwood is nearly white. The grain is usually straight and even, especially in virgin timber. Second growth is coarser textured, knotty, and more likely to be coarse grained. Virgin-growth white pine has always been noted for its soft, uniform texture.

Northern white pine is universally recognized as one of the best woods for millwork and is also highly desirable for general construction purposes. It dries rapidly and does not shrink or swell to any great extent. It is probably the least resinous of any of the pines; is easily worked and

changes shape very little with moisture changes. For this reason, pattern makers and woodworkers usually prefer it.

The Norway or red pine, also found in the white-pine region, has many of the characteristics of the northern white pine, except that its color is slightly reddish, with a wide, light-yellowish sapwood, and that it is coarse grained and somewhat inclined to be brash.

SUGAR PINE

Of the dozen or so botanical species of true white pine grown in the United States, three are of outstanding importance in the lumber industry, namely, northern white pine, Idaho white pine, and sugar pine. Sugar pine is primarily a native of California and southern Oregon, and this region is the source of commercial sugar pine. In California, it grows to a large size and is considered one of the most valuable timber trees because of its inherent qualities. Sugar pine is found in rich, loose, sandy loam, where it reaches its best development.

In general, it has many of the properties of northern white pine, but its lumber can be obtained in larger sizes. Sugar pine can be classified among the durable species of white pine. It usually is lighter colored, changes color less on exposure, has more conspicuous resin ducts, and is slightly coarser textured than the other two white pines, northern white pine and Idaho white pine. It is light in weight, comparatively free from defects, straight grained, and easily worked. The heartwood is cream colored, darkening slightly upon exposure. Since sugar pine is the largest of the white pines, a great deal of the lumber from it is cut into wide widths of thick stock. It is estimated that over 50 per cent goes into the manufacture of planing-mill products, such as sash, blinds, and millwork. A large percentage of this species is used for pattern work. It is free from a tendency to warp and twist and holds its shape well after being dried.

IDAHO WHITE PINE

Idaho white pine, or *Idaho pine*, as it is sometimes called, is another of the three commercial species of genuine white pines found in the United States (*Western white pine* is its scientific common name). It obtains its best growth in northern Idaho, eastern Washington, and western Montana and is found in the mountains at an elevation of 2,000 to 7,000 ft., in a variety of soils. Although Idaho white pine resembles northern white pine closely, it can usually be distinguished by the color of its knots, which ordinarily are darker around the edges than the knots of northern white pine. Pattern makers often claim that they can distinguish the clear wood of Idaho white pine from that of northern white pine by a difference in workability, although both woods are equally fine textured. Idaho white pine is light in color, light in weight, straight grained, and durable. It shrinks and swells a little more, with changes

in moisture content, but on the whole it compares favorably with northern white pine. The lower grades are being used extensively for knotty pine paneling, pattern making, cornice and porch work, and general construction purposes, while the higher grades are shipped to eastern markets and used for about the same purposes as northern white pine, including siding and special or made-to-order millwork items and carved and turned work.

PONDOSA PINE OR CALIFORNIA WHITE PINE

Another important western pine, which approaches the true white pines in properties and characteristics and which is used for many of the same purposes, is that known in the lumber markets as Pondosa pine or California white pine. The lumber sold under these names is cut from the same species, known botanically as *Western yellow pine* (*Pinus ponderosa*). It grows throughout the Rocky Mountains and westward to the Pacific. Because this wood is cut over such a wide territory the trade has developed a number of trade-names which are used to designate it when originating in different regions.

The following terminology covers lumber from this species cut in various localities and regions: Arizona white pine, California white pine, Oregon white pine, Oregon pine, Pondosa pine, western pine, and western white pine. *Pondosa pine* is the name applied to it in Idaho, western Montana, eastern Washington, and central Oregon. That originating in California and southern Oregon is sold under the trade name, *California white pine*. These two regions produce almost 90 per cent of the total cut of this wood.

Generally, the wood of the Pondosa pine produced in Arizona and New Mexico is coarse grained, compared with that of northern white pine, and has a pronounced zone of springwood and summerwood. The heartwood is light reddish brown in color.

The Pondosa pine which grows in California and the Inland Empire region closely resembles northern white pine in many respects, and it is put to many of the same uses. Its color varies from creamy white to straw. The wood is light, usually extremely straight, fine grained, easy to work, and not subject to grain raising.

Because of its low-density cell structure it is an excellent insulating material. Oregon and California furnish the bulk of the cut of Pondosa pine.

One of the chief uses of the wood is in the sash and door field and in millwork of all kinds. Probably as high as 25 per cent of the production goes directly into such uses. It is extensively used as a general house-building wood for sheathing, siding, interior and exterior finish, and molding.

EASTERN SPRUCE

The eastern spruces have been separated into three groups—white, red, and black. The woods are much alike and resemble each other closely in their general structure. Early in the history of the first New England settlement, spruce was established as a valuable wood for shipbuilding, framing, and general construction work and was used as a substitute for northern white pine in this region, when the supply of northern white pine began to decline. At present, although the production of eastern spruce is very small, the species is important in some localities. In the wood-using industries, in general, the red spruce is the most important of the three, inasmuch as it is somewhat lighter and straighter grained and more even textured than the white or black spruces. The white spruce is usually coarser grained than the others. The black and white spruces are similar in quality and are not separated in the trade. The heartwood of the red spruce is nearly white, with a slightly reddish tinge, while the white spruce has a light-yellow heartwood. The wood of the red spruce is light, straight grained, and even textured, with a light yellowish-brown heartwood and a nearly white sapwood. It has a pearly luster and is exceptionally strong for its weight, except where it is weakened by spiral grain or some other defects. All three of the spruces are used in millwork and in concrete form work; locally, spruce is used in all general building. A large proportion of its lumber is used in general construction, especially for studding, scaffolding, and lathing.

SITKA SPRUCE

Sitka spruce, one of the most important varieties of spruces in the United States, obtains its best development in Washington and Oregon, in deep rich soils, throughout the greater part of its range. Its range extends north through British Columbia into Alaska. This spruce attains a large size, reaching heights of from 275 to 300 ft. and a diameter of 8 ft. Hence, it produces lumber in larger size than the eastern species of spruce. There is considerable variation in the texture, grain, and strength of this species. The wood is light in weight and the heartwood is straw colored to pinkish, with a thin, lighter-colored sapwood. The grain is very straight, the growth rings are even and narrow and, hence, form an even-grained wood. The wood when freshly sawed is almost white and develops its color upon exposure to the air. It is comparatively free from warping and checking and is easily dried. Its best known use is probably in airplane construction, for which it is suitable on account of its texture, strength, lightness, and shock-resisting qualities, but it is also suitable and widely used for interior and exterior finish, siding, general construction work, and cabinet work. In equivalent

grades, Sitka spruce is fully equal in mechanical properties to the eastern spruces and, hence, has found favor in the eastern markets.

LARCH AND TAMARACK

(WESTERN LARCH AND EASTERN TAMARACK)

The terms *larch* and *tamarack* apply to different but related species. Larch is used in connection with the western wood, and tamarack in connection with the eastern species. A great many local names have been developed, according to the particular region in which the species is cut. They are both members of the same genus Larix.

The western larch is a large tree, at its best on fertile soil in western Montana and northern Idaho, and develops its greatest sizes where the soil is moist, rich, and deep. The wood is moderately heavy, straight grained, durable, light to deep reddish or chocolate brown in color. In general, the lumber is of better quality than that of the eastern tamarack. A large percentage is produced in the select grades and has much the same uses as Douglas fir. Practically three-fourths of the western larch goes into square-edged boards and dimension, where straightness of grain, durability, strength, and freedom from defects are desired. A large portion also goes into the manufacture of telephone poles, rough flooring, and bridge decking and when cut to produce edge-grained stock, makes good finish flooring.

In the East, tamarack is found in wet or swampy areas although there are exceptions, for in the North its distribution is more varied. The wood produces little material of the select grades; it is heavy, strong, coarse grained, generally straight grained, durable, but inclined to warp when drying. The heartwood is light brown, and the narrow band of sapwood is nearly white. Season or spring- and summerwood zones are very conspicuous and striking. Practically all of the lumber is used for such purposes as posts and poles and, to some extent, for general construction and millwork.

SOUTHERN CYPRESS

Southern cypress (*Taxodium distichum*), grows in low swamp lands along the Atlantic Coast from Virginia to Florida, westward on the Gulf of Mexico to Texas, and up the Mississippi Valley as far as Missouri. The wood is variously known as *red, black, white,* and *yellow cypress.*

The United States Department of Commerce in its standardization program for lumber, as outlined in *Bulletin* 16, has assigned to the various types of cypress the following standard commercial names to be used in the construction of contracts and in the formulation of lumber-grading rules, and the terms of purchase and sale of American Standard Lumber.

Standard Commercial Name	Botanical Name
Red cypress (coast type)	*Taxodium distichum*
Yellow cypress (inland type)	*Taxodium distichum*
White cypress (inland type)	*Taxodium distichum*

Cypress grown in the deep swamps of the coastal plains regions near tidewater is now commercially called *tidewater red cypress* to distinguish it from the inland or upland cypresses, which are lighter in color and not so durable.

Cypress heartwood is variable in color. The tidewater cypress (that is, the cypress close to salt water) will vary from slightly reddish to a deeper red, and much of it will be almost black with intermediate gradations. Away from the salt water, the heartwood is usually slightly reddish or even lighter in color.

Cypress heartwood is one of the most decay-resistant kinds of lumber manufactured. The great durability of the heartwood, probably more than any other property, gives cypress the place of distinction which it holds among the more valuable woods on the market.

In respect to strength, cypress holds a position intermediate between that of the light and the heavy yellow pines.

Cypress has a great variety of uses, and for many of these it is selected as a preferred material. The key to its usefulness is its resistance to decay and other forms of deterioration when in contact with moisture, and its quality of being easily worked. It is used extensively for outside finish of buildings, such as siding, casing, sash, doors and blinds, cornice, railings, steps and porch material. As a gutter stock, cypress outlasts many other materials and is in favor for high-grade work. Standard planing products consume large quantities of cypress. These include ceiling, siding, flooring, molding, and finish. On account of its freedom from taste and great durability it is a preferred material for tanks, vats, tubs, and wooden buckets. These are used for water storage and by creameries, breweries, bakeries, dye works, distilleries, and soap and starch factories. In the construction of greenhouses where wood is subjected to extremes of heat and moisture, cypress is used probably more than any other wood.

In recent years it has come into particular favor in constructing tanks and vats used in various chemical industries.

REDWOOD

On the immediate Pacific Coast slope of the Coast Range Mountains in California, in a narrow strip 10 to 30 miles wide, and south from the Oregon line in the north to a point just south of Santa Barbara, is found the redwood of commerce, *Sequoia sempervirens*.

Here and here only (for the redwood forest grows naturally in no other place in the world) are to be found the heaviest stands of timber in the

United States, with individual trees ranging in diameter up to 20 ft. and in height up to 368 ft.; with single trees estimated to contain more than 300,000 ft. board measure; with measured acres having cut more than 1,000,000 ft. board measure per acre; with entire tracts averaging 150,000 to 200,000 ft. board measure.

The sapwood of redwood, which is confined to a very narrow band, is almost white and presents a startling and clearly defined contrast to the distinctive heartwood, which varies in color from cherry to dark mahogany.

Redwood is one of the most durable woods, ranking in this respect with the cedars (excepting southern white cedar) and cypress—all of which are more durable than Douglas fir, the pines, the hemlocks, and the true firs. The ease and definiteness with which its unusually high percentage of heartwood can be distinguished from the less durable sapwood, and its high resistance to termites, make untreated redwood particularly suitable for use in foundation work, including mud sills; for fence posts, grape stakes, tunnel timbers, railroad ties, tanks, pipe, greenhouses, as well as for siding, exterior trim, shingles, and other uses where wood comes in contact with the ground or is exposed to the elements.

Besides being unusually durable, this wood is generally straight grained, comparatively light in weight, and non-resinous. It checks but little even when exposed to the sun and, due to a minimum of shrinkage when properly seasoned, is classed in use as a "still" wood.

Redwood, although softer than the southern pines (longleaf, shortleaf and loblolly), is harder than the white pines, ranking, according to the Forest Products Laboratory, with Douglas fir in this respect. Its extremely high percentage of clear lumber, and the ease (because of the great diameter of the trees) with which unusually wide, clear boards and large timbers can be obtained, have led to its wide use for beamed ceilings, paneled and wainscoted walls in homes, churches, and auditoriums.

Redwood has long been used extensively in the manufacture of sash, doors, frames, and trim as well as for all kinds of construction and finishing purposes on the Pacific Coast. During recent years, redwood, in shop grades, has found an increasing use in sash, doors, frames, and general cut-up stock, within the Middle West and Eastern markets. The ease with which all-heart material can be obtained (because of the high percentage of heartwood in the tree) and the great durability of that heartwood, untreated, coupled with its lightness of weight for relatively high strength has lead to an increasing use of redwood for heavy construction, such as state and county highway bridges and trestles, cotton- and paper-mill roofs, and similar structures.

THE HEMLOCKS

There are two principal species of hemlock which afford the commercial supply of hemlock lumber. They are the eastern hemlock, which grows principally in Wisconsin, Michigan, Pennsylvania, New York, New England, Virginia, and the Carolinas, and West Coast hemlock, which is a western species found in Washington and Oregon. Neither eastern, nor West Coast hemlock lumber contains any pitch, an interesting point to consider in connection with a number of uses.

Eastern Hemlock.—Eastern hemlock is light, straight, fine textured, and at times somewhat splintery in the rough or when it has not been properly milled. In contact with the soil, it is not classified among the durable woods, but it is very seldom that it is subject to dry rot in buildings, and, in Wisconsin, and Michigan, such reports are unknown. The heartwood is light brown, while the sapwood is still lighter in color.

In the early days, when the producers of white pine began cutting some hemlock and marketing it "log run" or "mill run," with practically no grading, the hemlock lumber reaching the market naturally did not compare well, in appearance or quality, with the graded product of other species. The early reputation thus gained has been lived down through the adoption of standard grade practices by the chief producers. In Wisconsin and Michigan, where the bulk of this species is now manufactured, the wood is known as *northern hemlock*. It is graded strictly according to American Lumber Standards, and the 2-in. stock is cut extra thick (industrial standard, or extra standard), thus counterbalancing in extra material the slightly greater strength of some other structural woods. The knots in northern hemlock are characteristically small. The northern hemlock producers of Wisconsin and Michigan trade mark, grade mark, and brand their lumber so that the consumer may be assured of standard grades and standard, or extra-standard sizes. Due to the careful manufacture and grading of the present day, eastern hemlock can be purchased in grades which are excellently suited for general building and construction uses. Northern hemlock is the principal structural lumber today in Wisconsin, Northern Michigan, and the greater part of Southern Michigan.

West Coast Hemlock.—Companion to the giant Douglas fir in the forests of the West Coast grows the West Coast hemlock. This species produces a wood of high character which has many important building and industrial uses. The wood of the West Coast hemlock is hard, strong, and stiff and is highly prized for flooring, paneling, and interior trim. It has a delicate, pleasing pattern in the flat grain and, because of the large size of the trees, can be obtained in wide, clear sizes in vertical-grained stock.

From 12 to 14 per cent of the total production of lumber from the west coast of Oregon and Washington is West Coast hemlock. For years

the common dimension stock of this product has been distributed through out the United States, often mixed as an equivalent wood with Douglas fir It has smaller knots generally than the Douglas fir and although not s strong usually contains a greater percentage of clear wood in the commo grades; so that, grade for grade, in the commons, West Coast hemloc for ordinary construction uses is usually accepted as the equal of Dougla fir.

THE CEDARS

The term *cedar* is a general name for all of the fragrantly scente softwoods. In the trade, cedar is classified into several groups—namel northern and southern white cedar, eastern red cedar, western red cedar incense cedar, and yellow cedar or cypresses.

The commercial supply of white cedar is furnished by the northe white cedar and southern white cedar, both of which have comparabl structural features. The northern white cedar, however, is a somewha smaller tree and does not grow to so large a size as the southern whit cedar. The wood of the northern white cedar is very light, soft, brash aromatic, weak, fine grained, fine textured, with a light-brown to pale brown color; the sapwood narrow and nearly white. It is not very strong but is naturally very resistant to decay and is used for construction in th form of poles, posts, and shingles. The southern white cedar is pinkis in color, firmer, and more highly scented. It is used principally for boat and shipbuilding as well as for posts, poles, and shingles. A smal amount enters into the building and construction field in the form of roug lumber.

Eastern red cedar is sometimes referred to as *pencil cedar* or *aromati red cedar*, and obtains its best growth in rich, damp soils throughout th southern part of its range. Perhaps its best development is obtained i Tennessee. The wood is light, aromatic, durable, and generally knotty It is one of the few woods in which defects of this nature add to its value The heartwood is purplish red, and the sapwood is pale yellow to white It is fine grained and fine textured. The growth rings are uneven, wit narrow summerwood bands. Eastern red cedar takes a high polish an is very pleasing when finished in its natural color. At the present time there are a number of companies specializing in the manufacture of east ern red cedar into interior siding for use in moth-proof closets.

Western red cedar is the largest of any of the cedars. It is more or les confined to the Pacific Northwest and extends from Oregon north t Alaska. It appears to be restricted to wet and damp valleys in thos regions in which atmospheric humidity is high. In the United States it i cut commercially in Washington, Oregon, and northern Idaho. The woo is reddish brown in color, light in weight, soft, brittle, aromatic, eve

textured, even grained, and remarkably durable when placed in contact with the soil. Its structure compares favorably with the northern white cedar, except that it is coarser in texture. It is entirely free from pitch, finishes well, and has good nail-holding qualities. Because of its large size, the logs yield wide, clear lumber that shows practically no tendency to warp and check. Is is comparatively easy to kiln dry and holds its position well after being seasoned. More than half the total cut is sawed into finished lumber and used for planing-mill products, with a somewhat lesser quantity going into shipbuilding. A large amount is manufactured into bevel siding and into shingles, which are noted for retaining their flatness and are said to last for from 40 to 50 years when nailed with copper- or zinc-clad nails and cut from thick, even-grained lumber free from sap. These shingles take and hold stain of the finest tint without discoloration. A large quantity of this timber is also used for rough construction purposes in the form of piling, posts, and poles.

Incense cedar is an important species in California and southern Oregon. The wood is soft, light, weak, very durable, and possesses a slight peppery odor, which is characteristic of the species. It is somewhat similar in texture to eastern red cedar, for which it is used as a substitute, to some extent, in the manufacture of pencils; one of the common characteristics and defects of this tree is "peckiness." Incense cedar is used primarily for laths, shingles, posts, and interior finish. Its durability makes it a valuable wood for use when exposed to weather and adverse moisture conditions.

The Alaska cedar of the West Coast is often referred to as *yellow cypress*, *Alaskan yellow* or *yellow cedar*, and is of the same genus as the southern white cedar. The tree is typically a West Coast species, which extends from Alaska to California, and considerable quantities of its timber are cut in Washington, which supplies the bulk of this lumber for commercial purposes. The wood is strongly aromatic, with a characteristic odor, which is sometimes compared to the odor of rotten potatoes. The wood of the yellow cedar is perhaps the strongest of any of the so-called *cedars;* it takes a fine polish, is durable, and can be used safely under conditions where moisture is extreme. It is used for practically the same purposes as southern white cedar. A large amount of this wood goes into the production of veneers, which are used for paneling purposes, and built-up stock.

Port Orford cedar is restricted in its distribution to the Pacific Northwest and has its best development in Oregon, which supplies the great bulk of this lumber for the trade. The wood has a somewhat brownish appearance, is firm and strong and highly scented. It is manufactured into siding, chests, closet-lining stock, shingles, and rough construction products such as posts, poles, and piling.

THE OAKS

(RED AND WHITE)

Oaks are among the most important trees grown in the United States. A large proportion of the commercial oaks comes from the South and the Mississippi Valley; they form the most important wood grown in the Appalachian region. They are particularly an eastern species. There are some 60 species of oak, but only 12 or 14 are of commercial importance. According to their structure, characteristics, and uses they are divided into two main groups, the white oak group and the red oak group. All oaks have many properties in common, being hard, heavy, strong, fairly easy to work, taking a good finish, and showing a characteristic figure on quarter-sawed surfaces. There will be found a considerable variation in the quality of the wood, not only in different species but also in different trees of the same species, as a result of age, rate of growth, and character of the soil. Wood from the old trees of slow growth is the mellowest. The white oaks are better for some purposes, being more durable, less porous, and of lighter color than the red oaks. The strongest and toughest of any of the oaks is produced from the so-called *live oaks* used almost entirely in shipbuilding. Red oaks differ from the white oaks chiefly in their somewhat deeper reddish-brown heartwood and in being less resistant to decay. In the trade, special preference is shown for the so-called *soft-textured* varieties of white oak, which are characteristic of the southern Appalachians and are known as *chestnut oak*. The true white oak (*Quercus alba*) and the variety of white oak called *chestnut oak* (*Quercus prinus*) make up the great bulk of the commercial Appalachian white oak. *Forked-leaf white oak* is a trade name referring to white oak which is soft textured and has a slight pinkish tinge. Some difficulty is experienced in the kiln drying and in the seasoning of some of the swamp varieties, and they are subject to excessive checking unless properly handled. The principal uses of oak are for furniture and cabinet work, interior trim, paneling, flooring, tight cooperage, heavy construction, such as railroad trestles, piling and caps, cross-ties, and poles.

CHESTNUT

Two decades ago, chestnut was one of our most promising forest species and an important timber in southern New England and New York; but it is now limited to the southern Appalachians because of an attack of the chestnut blight, which has already killed most of the stand north of the Mason and Dixon line. The blight is caused by a bark-inhabiting fungus imported from Asia some time previous to 1904. The Forest Products Laboratory has carried on a series of tests with blight-killed chestnut, which show that the blight fungus is not directly responsible for any reduction in the strength or quality of the timber. The

disease merely has the effect of girdling the trees, thus causing their death. Despite exhaustive research on the subject, no means of controlling the blight has been found. The complete destruction of the present stands seems inevitable. There are, however, a few trees throughout the killed areas which show varying degrees of resistance. It is possible that the most promising of these will furnish a strain sufficiently safe for propagation at some future date. Since the present chestnut stands cannot be saved, the immediate problem resolves itself into one of salvaging as much of the timber as possible with the least reduction in profits to owners and of replenishing the ground with other suitable forest trees.

Chestnut wood is light in weight, soft, not strong, coarse grained, stiff but brittle, non-elastic, easily seasoned, easily split, easy to work, and very durable in contact with soil. Because of this durability, it is used in large quantities in caskets and coffins. It is suitable for general construction work because it is durable and has practically the same strength as white pine, spruce, and hemlock. It will also serve for sheathing barns and sheds. The wood has an attractive figure and takes finish well, which fits it for interior and cabinet work. It is hard enough for flooring and is used to some extent for doors and for door and window frames. Because it changes shape very little with changes in moisture content, it is used widely for core stock in veneered panels.

THE ELMS

The elms are among the important commercial woods of the United States. They are important because they have qualities that make them especially adaptable for bent work and uses where shock or impact and rough usage in general are to be considered. Five species of elm supply this type of lumber in the United States: white elm, slippery elm, cork elm (rock elm), wing elm, and cedar elm. The proportion which each contributes to the lumber industry is not known, since they are often mixed together and are generally listed as "elm" in reports of manufacturers of elm lumber and elm products. White elm is the most important in the matter of production and is often called *gray elm* in the Lake states, and in foreign countries *American elm*. Cork elm, commonly referred to in the trades as *rock elm*, is hard and very dense and has higher strength values than either white or slippery elm. Wing elm and cedar elm are not commercially important. Only a small proportion of elm is used in the rough for building construction, but it is estimated that from 6,000,000 to 8,000,000 ft. are used annually for interior trim and finish. Elm is used as an inside finish wood, because of its moderate amount of figure and pleasing light and dark shades when finished in the natural color and of the good appearance it makes in panels. It is used to imitate more expensive

woods, such as plain oak, though laboratory information indicates tha it is at best only a substitute for better woods.

SYCAMORE

Practically all of our native sycamore wood comes from a singl species which grows throughout nearly all of the eastern half of th United States. It is commonly called in certain localities *buttonwood buttonball*, or *plane tree*. The principal supply is found along the rive bottoms adjacent to the large streams and tributaries of the Mississipp River. It is more or less scattered in growth. Sycamore, in general, i a uniformly colored, clean-looking wood and presents a good appearanc when manufactured. Plain-sawed sycamore has little figure, excepting the lighter-colored bands which mark off the annual growth layers fron each other, and is very difficult to dry without warping. In quarter sawed stock the rays are very conspicuous and resemble the figure i quartered oak, although, as in most woods, the rays are darker than th rest of the wood, while in oak they are about the same color; it does no warp so readily as the plain-sawed timber but is more difficult to dry Sycamore is moderately hard, moderately heavy, moderately stiff moderately strong, has moderately good shock-resisting ability, and i difficult to split. It shrinks moderately and is inclined to warp, but no excessively, in seasoning. It can be easily kiln dried, but care must b taken in the proper handling and piling to prevent warp. Sycamore i not durable, the average life of the untreated lumber being placed a about 5 years under exposed conditions. It is highly prized for interio trim and fancy paneling. It is also desirable for doors, especially whe the veneer is used and panels are built up.

BEECH

The commercial beech in the United States is restricted to one species which has a wide range over the eastern part of this country. In th trade it is commonly spoken of as *red beech* and *white beech*, which indicat respectively, the heartwood and sapwood of the tree; the contrast betwee the two is not very marked, the heartwood showing a slight reddish ting and the sapwood being a decided white. In the forests, beech occasion ally occurs in pure and solid stands, but it is also widely scattere among its close associates, birch and maple. It was formerly ver abundant, but much of it has been eliminated in the clearing up of timbe lands for farming purposes, where it was considered a pest and was cu and burned to rid the farmer of it. Beech is one of the woods which we not utilized until comparatively recent years. The American beech closely associated with the European species but is not considered s good in quality and workability. Considerable trouble is experienced i drying beech, inasmuch as it shows a marked tendency toward warpi

and excessive checking. Modern kiln-drying methods, however, are overcoming most of this difficulty. Beech is hard, heavy, and strong and can be worked rather well with tools. It is intermediate between sycamore and hard maple in most of its properties. It has considerable shock-resisting ability, and its abrasive qualities are excellent but inferior to those of hard maple. When dry, beech stays in place well and has excellent nail-holding ability. Beech is widely used in the turning industry because it turns well and can be given a smooth, hard finish. Practically one-quarter of the production of beech is used in planing-mill products, the balance going into the manufacture of furniture stock, handles, woodenware and novelties, laundry appliances, brushes, vehicle parts, agricultural implements, and miscellaneous products. Beech is also manufactured into flooring, as it has excellent wearing qualities.

THE BIRCHES

Although there are several species of birch trees scattered over the United States, practically all of the lumber for commercial purposes is obtained from the two species—yellow birch and sweet birch. Yellow birch is cut chiefly in the Lake states and to a lesser extent, in New York and New England, while sweet birch is cut in Pennsylvania and West Virginia. The most important source of this lumber is the Lake states region, where it has been long associated with beech and the maples. The sapwood of both species is known as *white birch*, and the heartwood as *red birch*. The sweet birch is slightly harder and stronger than the yellow birch, though most of the birch used for flooring and finish is of the latter species. Birch wood is fine and even textured, hard, strong, takes a high polish and a beautiful natural or stained finish. Architects seem to have some difficulty in understanding the distinction between *selected*, *unselected*, and *curly birch* and in making this distinction clear in their specifications. *Selected* and *unselected* refer to color and not to grade and indicate that the lumber has or has not been selected for uniformity of color. Birch is one of the few woods which, when finished in the medium- and darker-toned stains, will not show the difference between the light-colored sapwood and the darker, reddish-colored heartwood. For this reason, *unselected* can often be specified with a marked saving in cost. On account of the light tone of the natural birch wood, it is well adapted to the new and delicate color stains which are finding favor among architects and furniture manufacturers. As a base for white enamel it is unexcelled, because its hardy, uniform, dense surface, free from markings caused by large groups of pores guarantees a permanent smooth surface. Birch was formerly much used to imitate mahogany and other woods but has now won a place on its own merits. Large quantities of birch are now used in the production of veneers, for interior trim, doors and panels, and flooring.

THE MAPLES

(HARD AND SOFT)

The various maples are divided into two main groups—hard maple and soft maple. Hard maple is sometimes referred to as *sugar maple, sugar tree, rock maple, black maple, sweet maple,* and *white maple,* the last names being of white stock cut from hard maple trees. The name is dependent upon the particular region in which the lumber is produced. Lumber marketed as soft maple is produced from two species—silver maple and red maple. The soft maples are sometimes referred to as *silver maple, silver-leaf maple, river maple,* and *white maple.*

The great bulk of hard-maple lumber is produced in the Lake states and is found there in rich sand with other northern hardwoods, namely, birch, and beech. Smaller quantities are cut in the Appalachians, Pennsylvania, and New York. Hard maple is strong, heavy, hard, fine grained and fine textured. The heartwood is light reddish brown with deeper-colored summerwood bands. The sapwood is white in color and furnishes the "white maple" prized for certain uses. It differs mainly from the soft maples in its greater density and finer texture. The wood is comparatively easy to work, rather difficult to dry, holds its position well, and is susceptible of a fine polish, stain, and finish. It is one of the most important of American hardwoods. Practically one-third of the total cut of hard maple goes into planing-mill products, the most important of which is flooring. Maple is also used for interior trim. It takes a pure ivory-white finish, which is much desired for this type of work. It is also peculiarly adapted to the recently developed color stains which require a white wood as a base for the most delicate effects. The allied species, red maple and silver maple, are similar in distribution and properties, except that they are weaker, softer, and lighter than the sugar maple. The silver maple or true soft maple is weaker than the red maple and will show somewhat lower mechanical properties. A considerable quantity of maplewood is used in the production of veneers, for the manufacture of doors and panels. Maple is also used for stair treads, as it is hard and gives excellent service.

CHERRY

Cherry, because of its relative scarcity, is not at present used extensively, although it has excellent qualities for varied purposes. In former times, cherry was looked upon as a valuable wood for the manufacture of cabinet work and interior trim. In the forest it is never found in large quantities and consequently has no well-defined commercial range. The tree grows throughout the whole of the eastern part of the United States but is cut commercially chiefly in Pennsylvania, West Virginia, New York, and Ohio. As a general rule, it prefers rich, deep soils, but is

by no means confined to them. Of the many species of cherry in the United States, only the black cherry supplies commercial lumber. The heartwood is a rich, reddish brown, and the sapwood is thin and very light brown. Owing to the rich color and its ability to take high polish it is used to a considerable extent for interior trim, in the finishing of electric cars, and for planing-mill products. Cherry is somewhat lighter in weight and a little softer than beech and birch but is nevertheless a dense, strong hardwood of excellent wearing qualities and pleasing color.

MAHOGANY

Although the name *mahogany* is applied commercially to more than 50 different woods only five species of true mahogany have been identified by botanists. There appears to be a widespread popular belief that true mahogany may be had from many parts of the world. As a matter of fact, true mahogany grows naturally only in the tropical part of Florida and the adjacent Keys, the West Indies, and on the eastern coast of Central America south to the northern part of South America. In addition to the true mahoganies, there are several so-called *mahoganies* which must be carefully differentiated from the genuine. Some of these so-called *varieties* bear little more than a general resemblance to true mahogany in their structure, though skilful finishing may make them much like it in outward appearance. The woods resembling mahogany, and at times confused with it, are primavera or white mahogany, Spanish cedar, tanguile and lauaan, formerly called *Philippine mahogany*, African mahogany, padouk, an East Indian wood of somewhat similar appearance, and gaboon, sometimes known as *Liberville mahogany*. Sometimes wood is classified in the trade as Cuban mahogany, Honduras mahogany, Mexican mahogany, etc., according to the country from which it is cut; but if the place of origin is not known, it cannot be determined from an examination of the wood. Mahogany is a truly tropical tree, solitary in growth, reaching great height and size. All genuine mahogany lumber and veneers, regardless of origin, are divided into two classes with reference to the surface appearance. These classes are: plain and figured. Figure is spoken of as the effect that is produced by the interlocking and interlacing of the wood fibers. In plain mahogany the growth is regular, the grain straight with but little interlocking of fibers, and there are no prominent surface markings. Figure in mahogany is often spoken of as being "stripy figure," "broken stripe," "ribbon," "mottle," "raindrop," "fiddle-back," and "crotch." The value of individual mahogany logs depends primarily upon the kind and amount of figure; certain logs have been known to bring $3,000 to $5,000.

Mahogany is moderately strong, uniform in structure, and may be either moderately open grained or close grained, depending largely upon the locality where grown. The wood seasons with comparatively little

warping and checking and, once seasoned, shrinks and swells very little. This property of holding its shape, together with its handsome grain and figure, make it one of the most satisfactory cabinet woods. It takes a beautiful natural wood polish and is well adapted to stain. The mahogany produced in Florida is, perhaps, the darkest and hardest of any of the species. Mahogany is principally used in the furniture trade. A considerable amount is used for the interior finish of fine office buildings, hotels, and dwellings. Likewise, a large amount is worked into planing-mill products, such as doors, panels, interior trim, and fixtures.

BLACK WALNUT

The use of American black walnut for various purposes began in early Colonial times; probably its first extensive use was for fence rails, for which it was chosen because it was easy to split and resisted decay. Much of it was cut for fuel; large quantities of black walnut, which grows best on rich agricultural land, were wasted in clearings for cultivation. In the eighteenth century it was a favorite wood for furniture and was one of the two native woods (wild cherry being the other) best adapted for fine cabinet work. The excellent stands in the fertile valleys of eastern Pennsylvania were the main sources of supply, furnishing wood of a rich, dark color that was well liked. Walnut is not plentiful, in the sense of large quantities being available in one locality. Its growth is scattered. The exhaustion of the available supply has been repeatedly announced; nevertheless, during the World War large supplies were discovered, and many of the lots of large-sized trees that were found were equal in quality to those of the period when walnut was most popular. The annual cut of walnut timber is comparatively small, but a fairly steady supply is available because of the wide distribution of the tree. The heartwood of black walnut is light brown to dark brown or chocolate brown, and the sapwood, which is not prized so highly, is nearly white. In forest-grown trees the heartwood is generally rich, chocolate brown. Black walnut is heavy, hard, strong, and stiff. It is easy to split, has good shock-resisting qualities, shrinks moderately in seasoning, is susceptible of a good polish, and finishes exceedingly well. Its principal use is for furniture, interior trim, millwork, and cabinet work in general.

BUTTERNUT

Structurally, butternut is closely related to black walnut and is often called *white walnut*. It lacks the strength, rich color, and figure of the more valuable wood, although for many purposes it can be substituted with the application of a proper stain and finish to imitate this species. Butternut is limited and of scattered occurrence as a part of our forest growth. It is in much the same class as basswood and buckeye in respect to mechanical qualities but is slightly heavier, harder, stronger, and

tougher than these woods. It also has ability to take stains and finishes well. Only a small amount of butternut is used for planing-mill products in the form of interior trim and millwork.

COTTONWOOD

Thirty-five years ago, cottonwood had almost no value; today it is an important commercial tree. The wood, although not strong in comparison with the other woods, is strong in proportion to its weight. It is tough and extremely light when well dried, has a close, even texture, and is only moderately hard. It displays a tendency to warp and requires special care in piling. The sapwood, which is seldom more than 2 or 3 in. thick, is creamy white. When seasoned, the wood is almost tasteless and odorless and, as a general rule, works and finishes well. In certain trees, however, there is a tendency of the fiber to tear in sawing and planing, producing a characteristic brashy or woolly surface. Lumber of this character is often called *white cottonwood*, in distinction from the yellow, and is thought by some lumbermen to come from distinct species. Cottonwood has a wide range of uses and is being used for certain purposes in place of much more costly woods, such as white pine and yellow poplar. It is used (but not popularly) for partition, siding, and sheathing. When properly stained it makes remarkably attractive wainscoting, door panels, and balustrades. In certain sections of the South and Southwest, it is used extensively for barn framing and roof boards.

TUPELO

Twenty-five years ago, the commercial use of tupelo was practically unknown, and a great many mill operators in the South left it standing rather than cut it into lumber. As timber grew scarcer and stumpage prices higher, it became necessary to work out means and methods for its utilization and for better ways of handling it. The United States Forest Service became interested in this project and made a study of the subject. Today, tupelo is an important lumber in the United States and is being used for a great many purposes. It is principally a native of the low-lying, swampy regions in the South, closely associated with cypress and red gum, where it grows in so-called *tupelo thickets*. Tupelo is often called *bay poplar* and in the trade is often mixed with black gum, another species of the same genus as tupelo. These two woods resemble each other, and it is practically impossible to separate them without knowing the particular regions whence they were cut. Black gum, however, is slightly harder, heavier, tougher, and more disposed to warp and twist than tupelo. The wood of tupelo is uniformly white, is soft, fine textured, cross-grained, tough, strong, finishes smoothly, is inclined to warp, and very resistant to split. There is little distinction between the heartwood and sapwood. In its properties it is intermediate between cottonwood

and yellow poplar and is often substituted for them. Tupelo is used to a considerable extent for interior millwork and trim, being especially adaptable for use in flooring material where heavy wear and abrasion is an important factor. It is used in rough construction work in the form of bridge flooring, crossing plank, freight-house platforms, and decking for piers.

RED GUM

Red gum is one of the most common trees in the hardwood bottoms and drier swamp areas in the South and is unique among North American hardwoods in its development to its present usefulness. For many years, this species was considered as a "weed tree" and, therefore, undesirable in the exploitation of the more valuable hardwoods, such as yellow poplar and cypress. Because of its tendency to warp badly and the tendency of the sapwood to stain easily, it was not until 1903 that its importance as an American hardwood was recognized. Research and study were carried on to ascertain methods of handling, seasoning, and utilization. As a consequence, gum will give satisfactory results today if necessary precautions are observed and it is properly seasoned. Commercially, the term *red gum* applies to the heartwood of the red-gum tree, which belongs to an entirely different family than the black gum and tupelo gum in the trade. Botanically, it is not related to them. In the South, especially among lumbermen, there has been a tendency to designate sweet gum and red gum separately, although both refer to the same wood. The heartwood ranges from a slightly pinkish cast (*sweet gum*) to a deep reddish brown, while the sapwood is a creamy white. Due to some unknown characteristics of soil and site, certain red-gum trees produce what is known as figured red gum, which is highly prized for paneling.

The wood is fine and uniform in texture and takes a beautiful satiny finish but, as mentioned before, must be handled carefully to prevent warping. It is widely used for doors, interior finish, furniture, veneering, and panels and is furnished in plain- and quarter-sawed lumber and veneer. The quarter-sawed stock does not show so much tendency to warp as the plain-sawed lumber.

YELLOW POPLAR

Yellow poplar, also called *poplar*, is the tallest hardwood tree in the United States. The resemblance of its flower to the tulip has given it the name of *tulip tree* in some localities. Wood users in New England call the timber *whitewood*. Yellow poplar grows throughout the eastern United States but reaches its maximum development and produces its finest-textured woods in the sheltered coves of the Appalachians. The wood is rather light, soft to medium, fine textured, easy to work, finishes smoothly, and holds its place well when manufactured. It has moderate

shrinkage and dries well in kilns. It is easy to glue, and easy to nail because it does not split readily. It is durable and has excellent weathering qualities. It stains easily and uniformly, can be painted evenly and smoothly, and is excellent in taking and holding smooth, hard enamel finishes. The color of the heartwood varies from olive green to yellow or brown, often streaked with steel blue. The sapwood is white and in second-growth trees is very thick. Its uses are numerous and cover a wide range, the most prominent being in the manufacture of planing-mill products such as sash, doors, and general millwork.

BASSWOOD

Basswood is one of the important commercial trees of America. Its lumber is manufactured from two species but mainly from the species *Tilia glabra* which grows over nearly all of the eastern part of the United States and is cut chiefly in Wisconsin, Michigan, and West Virginia. It is also called *linden*, *bass*, *lime tree*, *whitewood*, and *beetree*. Basswood is well adapted for certain special uses where other woods do not serve so well, because it is easy to work, takes nails and screws well, and does not warp or twist easily. Because of the comparatively small supply now available it is greatly in demand for these purposes. It is valued highly for products made of wood in the natural state, particularly where a clean, attractive appearance and light weight are essential. The heartwood of basswood is creamy white, with occasional darker streaks. The sapwood is wide and not sharply defined from the heartwood. Because of its low strength properties it is not used for structural purposes. It is rated low in durability, the estimated life in damp places being approximately 3 to 5 years where it is not subjected to mechanical wear. If properly treated with preservatives its durability can be greatly increased.

References

United States Forest Service	Washington, D. C.
National Lumber Manufacturers Association	Washington, D. C.
California Redwood Association	San Francisco, California.
California White and Sugar Pine Manufacturers Association,	San Francisco, California.
Florida Dense Long Leaf Pine Manufacturers	Jacksonville, Florida.
Hardwood Manufacturers Institute	Memphis, Tennessee.
North Carolina Pine Association	Norfolk, Virginia and Macon, Georgia.
Northern Pine Manufacturers Association	Minneapolis, Minnesota.
Northern Hemlock and Hardwood Manufacturers Association	Oshkosh, Wisconsin.
Southern Cypress Manufacturers Association	New Orleans, Louisiana.
Southern Pine Association	New Orleans, Louisiana.
West Coast Lumbermen's Association	Seattle, Washington and Portland, Oregon.
Western Pine Manufacturers Association	Portland, Oregon.

CHAPTER IV

IDENTIFICATION OF COMMON WOODS

Easy methods of identifying common North American woods are described and illustrated in this chapter. The softwood and hardwood keys have been especially arranged to provide a simple means both of checking the surface appearance and structure of the woods most commonly used in building and construction and of differentiating between species.

Preceding each key is a list of the woods covered by the key. These lists definitely connect the commerical name of the lumber with a key number which corresponds to an index number in the key itself.

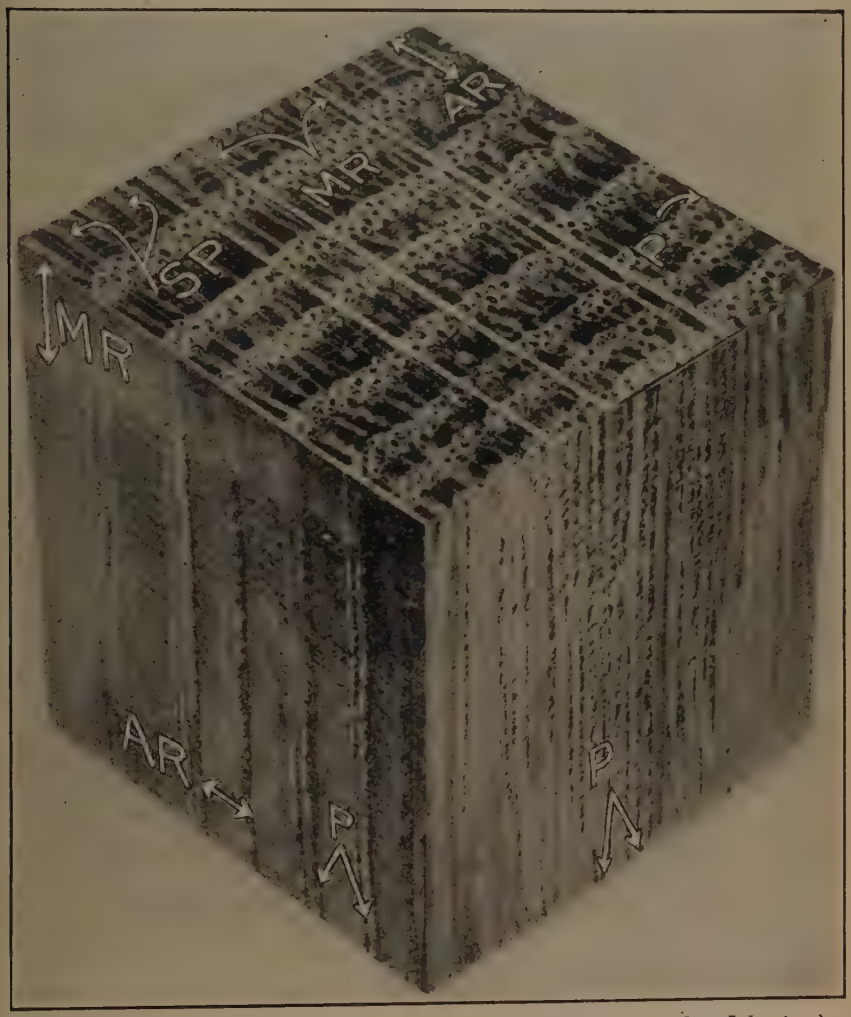
Technical names have been omitted from the key and technical phrases are used only when needed to differentiate one species from another. The illustrations show typical cross-sections of the woods described in the key. *Springwood* and *summerwood*, *parenchyma tissue*, *resin canals* and other somewhat unfamiliar terms used in the key are likewise illustrated.

An ordinary magnifying glass will be useful in examining the wood. It is advisable, if possible, to compare an unknown species with a known species.

The keys are based primarily upon the identification of a cross-sectional area, but frequently it will be necessary to work with both the radial and the tangential surfaces (see Fig. 27). A tangential surface or section can be secured by cutting at right angles to the wood rays. A radial section is one that is developed by cutting parallel to or along these same rays.

In identification work it is advisable to secure a piece of wood as large as possible, in order to get the general characteristics of grain, color, and average wood structure. It might also help to have a section showing pith and bark together with heartwood and sapwood, and of sufficient width to include three or more annual rings. A sharp, keen-bladed knife, which will produce a clean, smooth surface without tearing the tissue, should be used. Surfaces should be free from paint, stain, or varnish. A small drop of water on the surface of the wood will help bring out the wood structure. A hand lens will show the presence or absence of pores. Color—which, unless otherwise specified, always relates to a longitudinal section of a piece of dry wood—is also of value in identifying a species. If possible, observation of the color of both heartwood and sapwood is

advisable. In closely related conifers which, at times, are difficult to distinguish, a knowledge of the locality whence the specimens came, may be decisive.



(Courtesy Forest Products Laboratory.)

FIG. 27.—Cube of white oak wood magnified about 4.3 diameters. End surface at top; radial, or quarter-sawed, surface at left; tangential, or plain-sawed, surface at right. *AR*, annual rings; *P*, large pores containing tyloses; *SP*, small pores arranged in radial rows; *MR*, large medullary rays. Note very small rays between larger ones.

Figure 28 illustrates non-porous or softwoods, and both ring-porous and diffuse-porous or hardwoods. Before using the keys a wood should be related to its proper classification and identified either as a softwood or a hardwood.

Method of Determining an Unknown Species.—The following example will explain the method of determining a given unknown species.

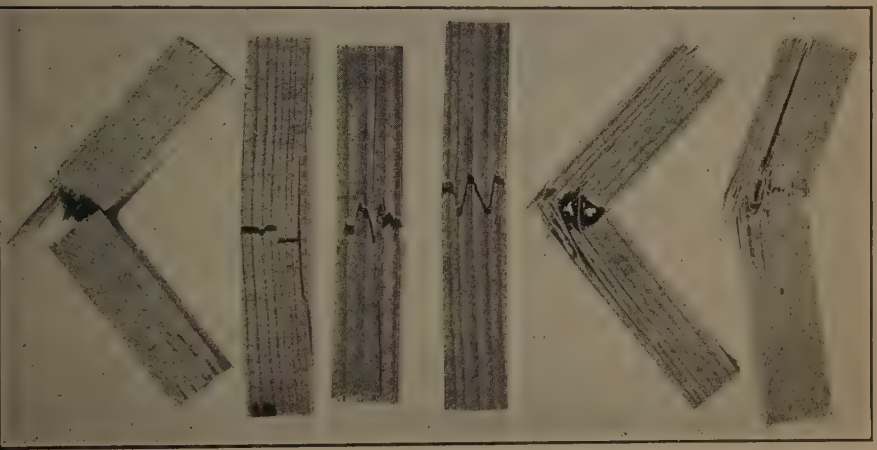
A *B* *C*

(*Courtsey Fosest Products Laboratory.*)

FIG. 28.—*A*—A cross-section of western larch, a non-porous wood (softwood) *B*—A cross-section of chestnut, a ring-porous wood (hardwood). *C*—A cross-section of yellow birch, a diffuse-porous wood (hardwood). All magnified 20 times.

The sample block of wood contains heartwood and sapwood, is approximately 4 in. wide, ½ in. thick, and 4 in. long.

The first thing to be determined in the identification of any species is whether it belongs to the conifer (softwood) or the hardwood group. The key starts out with the main heading: *A*. Wood without pores, and *B*. Wood with pores. After a smoothly cut surface has been made on a cross-section of the sample and viewed with a hand lens, it will be noted that there is an absence of pores. Consequently, the start in the key is made with *A*. Wood without pores, and according to the number opposite, we are referred to 1*A*, which states: "Resin canals (ducts) present," and 1*B*: "Resin canals (ducts) absent." Upon examination of the sample, it is found that resin canals are absent, and it is immediately identified as



A. Brash wood. *B*. Brash wood. *C*. Tough wood.
Courtesy Forest Products Laboratory.)

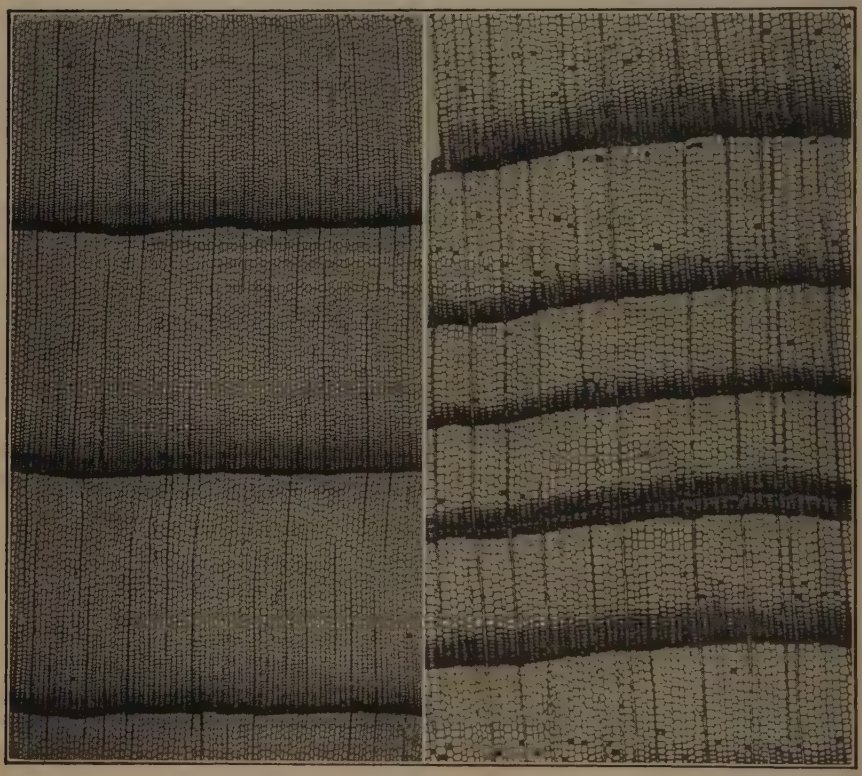
FIG. 29.—Typical fracture of brash and tough wood.

belonging under 1*B*, which refers us to No. 12 in the key. Number 12 states, *A*: "Wood with greasy feel, seasonal zones very variable in width and contour," and, *B*: "Wood without greasy feel, seasonal zones not strikingly variable in width and contour." Further examination of the sample will show that the wood is without a greasy appearance or feel; hence, 12*B* is taken, which refers to No. 13 in the key, where it is stated, *A*: "Wood without cedary odor on fresh-cut section," and, *B*: "Wood with cedary odor on fresh-cut section." The sample does not have a cedary odor; therefore 13*A* is taken, which refers to No. 14 in the key. Number 14*A* states: "Heartwood deep reddish brown, wood even grained, coarse textured, and brash,"[1] and 14*B* states: "Heartwood pale, never reddish

[1] The terms *grain* and *texture* in wood are very often used loosely and are misleading, inasmuch as *texture* particularly refers to the size of the cells and the proportional volume of the various tissues. Grain has to do with the cell elements and the arrangement of cells across the grain. For example, grain may be spoken of as fine or coarse, curly or interlocked, bird's-eye or gnarled. Texture may be fine or course with particular reference to the size of the cell (see Fig. 30.)

brown, wood fine to medium textured, heartwood pale roseate to lavender white, medium weight and strength, rings generally narrow, and shaky, with a tendency to be slightly brash" (see Fig. 29). The sample in question shows a deep reddish-brown color, the wood is even grained and extremely coarse textured, therefore, it comes under 14*A* and is redwood.

Comments on Wood Structure.[1]—By *hardwoods* is meant all native trees with broad leaves, such as oak, elm, and basswood; by *conifers* or



A *B*

(*Courtesy Forest Products Laboratory.*)

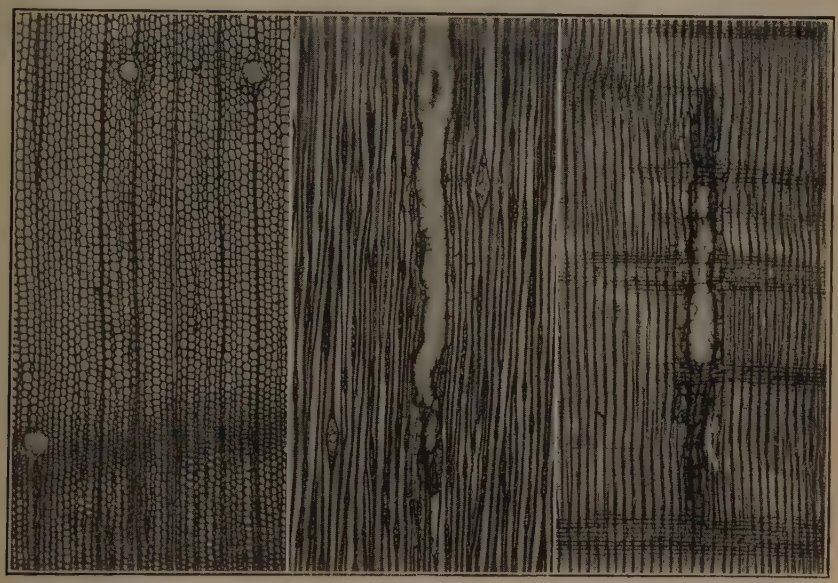
FIG. 30.—*A*—Cross-section of Western Red Cedar showing fine texture of wood. *B*—Cross-section of Redwood showing coarse texture of wood. Magnified 20 diameters.

softwoods is meant trees with needles or scale-like leaves, such as pine, fir, and cedar. The terms *hardwoods* and *softwoods* (or conifers) are not exactly correct designations for the two large classes of woods, for some so-called *conifers* do not bear cones. Other designations—such as porous and non-porous woods, woods from deciduous trees, woods from evergreen trees, woods from broad-leaved trees, and woods from trees with needles or scale-like leaves—are also inexact, because exceptions are found in

[1] See Chapter I, page 8.

both classes. The botanical terms *angiosperms* (meaning seeds enclosed in an ovary) for hardwoods—including palmlike trees—and *gymnosperms* (meaning seeds not enclosed in an ovary) for softwoods or conifers are consistent but are not in common use.

Nonporous woods are characterized by the absence of vessels,[1] and the wood is comparatively homogeneous in structure. The units of structure known as *tracheids* are fairly uniform and arranged in definite radial rows barely visible under the lens. The growth rings are usually distinct



A *B* *C*

(*Courtesy Forest Products Laboratory.*)

FIG. 31.—*A*—Cross-section, *B*—Tangential section, *C*— Radial section of Norway Pine showing resin canals. It will be noted that they extend vertically in the tree. All magnified 30 times.

on account of the abrupt change in density and color between the late wood of one year's growth and the early wood of the next year's growth. Resin ducts, when present, will classify the species in question as belonging to the non-porous woods.

To discover the resin ducts, a very smooth surface is necessary, since resin ducts frequently appear on the cross-section area only as fine white or darker spots normally scattered singly—rarely in groups—usually in the outer half of the springwood, or in the summerwood of the annual ring.

[1] *Vessels* are often spoken of in hardwoods as pores or cells and appear only in the broadleaf or hardwood species and consequently give rise to the term *porous woods*. As viewed under the hand lens in cross-section, these vessels or pores appear as somewhat large openings in the wood structure. Their primary function is the conduction of liquid (sap) in the tree. Their size and method of distribution are important as means of identification.

They are often much more easily seen on radial, and still more so on tangential, sections (see Fig. 31), appearing there as fine lines or dots of open structure of different color or as indentations or pin scratches in the tangential sections, inasmuch as they always run parallel to the grain of the wood.

In many temperate-zone hardwoods, the vessels are not all of the same size throughout the annual ring. This is especially noticeable in the so-called *ring-porous species*, and it will be seen that the springwood is largely occupied by very large vessels, with a tendency toward thin walls.[1] In the summerwood the vessels are more numerous but because they are smaller in size are less conspicuous. A contrast results which gives to the wood a definite zoning, or rings.

In diffuse-porous wood, there is usually no marked contrast of differentiation between the size of the vessels in the springwood or in the summerwood, and the pores are diffused over the entire area. Certain woods such as beech, birch, gum, and sycamore serve as typical examples of diffuse-porous woods. Certain of the other diffuse-porous woods, however, such as walnut and cherry, have a tendency to show a greater number of large vessels in the springwood than in the summerwood and are almost ring-porous.

Softwood Key[2]

(Conifers)

A. Wood without pores (vessels).....(conifers).....1
B. Wood with pores (vessels) .....(hardwoods).....18
1*A*. Resin canals (ducts) present.....2
1*B*. Resin canals (ducts) absent.....12
2*A*. Resin canals numerous, generally conspicuous, readily visible to the naked eye on most cross-sections, often forming dark lines on the faces of boards.....3
2*B*. Resin canals less numerous, scattered, small, scarcely visible, or not at all visible without hand lens, forming less conspicuous dark lines on faces of boards.....9

[1] Forsaith, C. C., "The Technology of New York State Timbers, *N. Y. State Coll. Forestry, Tech. Pub.* 18, p. 39, September, 1926.

[2] See Figs. 34 and 35.

3*A*. Wood soft, even grained (without pronounced summerwood), light in weight,[1] transition from springwood to summerwood gradual.....4

3*B*. Wood moderately soft to moderately hard, coarse grained except certain grades of western yellow pine (Pondosa or California white pine), transition from springwood to summerwood abrupt.....6

4*A*. Wood fine textured, resin canals appearing to the unaided eye as white flecks in cross-section, seasonal zones frequently wide, often of variable width, heartwood slightly reddish.....NORTHERN WHITE PINE

4*B*. Wood relatively coarse textured, resin canals appearing to the unaided eye as rounded openings in cross-section, seasonal zones generally narrow, of nearly uniform width.....5

5*A*. Resin canals often strikingly conspicuous as dark lines on the faces of boards, heartwood cream colored.....SUGAR PINE

5*B*. Resin canals usually not strikingly conspicuous on the faces of boards, heartwood slightly reddish...IDAHO WHITE PINE

6*A*. Bands of summerwood generally narrow and pale yellow in color.....CALIFORNIA WHITE PINE
PONDOSA PINE

6*B*. Bands of summerwood generally broad, wood varies from light in weight to extremely heavy and strong, generally strongly resinous, summerwood bands brown to reddish brown.....SOUTHERN PINES[2]

[1] The following scales of weight and hardness are used in describing woods:

Weight	Species for example	Hardness
Extremely light	.....	Extremely soft
Very, very light	.....	Very, very soft
Very light	.....	Very soft
Light	Basswood	Soft
Moderately light	Yellow poplar	Moderately soft
Moderately heavy	Black cherry	Moderately hard
Heavy	Yellow birch	Hard
Very heavy	True hickories	Very hard
Very, very heavy	.....	Very, very hard
Extremely heavy	.....	Extremely hard

KOEHLER, ARTHUR, "The Identification of Furniture Woods." U. S. Dept. Agr., *Misc. Circ.* 66, p. 74, 1926.

[2] For detailed discussion covering the separation of the southern pines, see p. 170.

7*A*. Wood light and very soft, yellowish white to reddish brown in color, summerwood rather narrow, usually non-resinous, sapwood thick.....8

7*B*. Wood rather heavy, considerable summerwood formation, containing heavy resinous deposit, ring growth narrow, sapwood thin.....LONGLEAF PINE

8*A*. Heartwood pale yellow, very light in weight, fine texture, easily worked, closely resembling white pine, ring growth narrow.....ARKANSAS SOFT PINE
SHORTLEAF PINE

8*B*. Heartwood reddish brown, wood frequently exhibiting tendency to brashness, often accompanied by wide annual rings, sapwood thick.....NORTH CAROLINA PINE
LOBLOLLY PINE

9*A*. Transition from springwood to summerwood gradual, summerwood formation not pronounced (see Fig. 32), texture fine,[1] little or no contrast between heartwood and sapwood, decided luster.....10

9*B*. Transition from springwood to summerwood generally abrupt, summerwood formation pronounced, wood cross-grained, no luster.....11

10*A*. Color white or very light, uniform, with little or no contrast between heartwood and sapwood, resin ducts scarcely visible without lens, wood soft, and light in weight.....EASTERN SPRUCES[2]

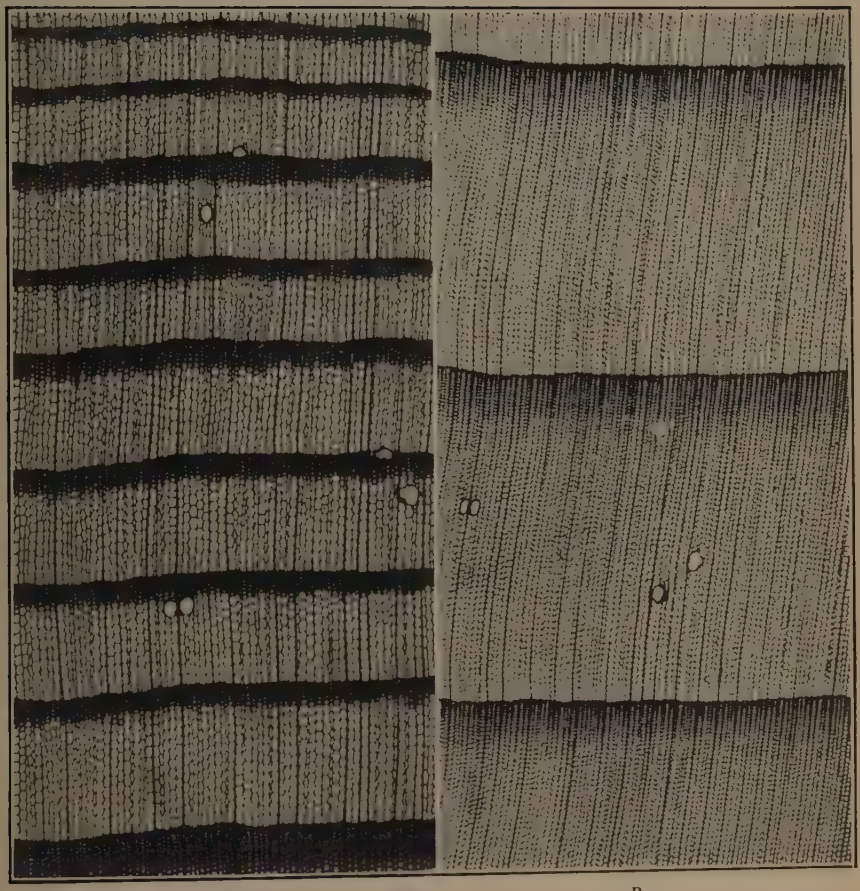
10*B*. Color reddish or pinkish, fading gradually outward to sapwood, texture rather woolly, resin ducts fairly distinct .....SITKA SPRUCE
WEST COAST SPRUCE

11*A*. Resin canals grouped in short tangential rows, wood with characteristic sweetish odor, heartwood varies from orange cast to deep red, sapwood yellowish, wood moderately light to moderately heavy and moderately soft to moderately hard, easily worked.....DOUGLAS FIR

11*B*. Resin canals small, scattered or rarely paired, wood usually moderately hard and moderately heavy, sometimes pitchy and highly resinous, sapwood thin, color yellowish brown to reddish brown.....TAMARACK OR WESTERN LARCH

[1] Since fineness of grain (*i.e.*, width of growth rings) is largely determined by external factors, it is an unreliable diagnostic feature and is resorted to here because constant features of distinction are apparently wanting and also because it is used to some extent by lumbermen. Samuel J. Record, "Economic Woods of the United States." John Wiley & Sons, Inc., 2nd Ed., 1919.

[2] For distinguishing characteristics, see p. 168.



A B

(*Courtesy Forest Products Laboratory.*)

FIG. 32.—*A*—Cross-section of Western Larch, showing *abrupt change* in Spring to Summerwood. *B*—Cross-section of White Spruce, showing *gradual change* in Spring to Summerwood. Magnified 20 diameters.

12*A*. Wood with greasy feel, seasonal zones very variable in width and contour.....SOUTHERN CYPRESS

12*B*. Wood without greasy feel, seasonal zones not strikingly variable in width and contour.....13

13*A*. Wood without cedary odor on fresh-cut section.....14

13*B*. Wood with cedary odor on fresh-cut section.....16

14*A*. Heartwood deep reddish brown, wood even grained, coarse textured, and brash.....REDWOOD

14*B*. Heartwood pale, never reddish brown, wood fine to medium textured, heartwood pale roseate to lavender white, medium weight and strength, rings generally narrow, and shaky, with a tendency to be slightly brash 15

15*A*. Wood coarse and uneven grained, seasonal zones variable in width, traumatic resin canals never present, wood brash .....EASTERN HEMLOCK

15*B*. Wood even grained, seasonal zones generally of nearly uniform width, traumatic resin canals sometimes present .....WEST COAST HEMLOCK

16*A*. Heartwood wine red to reddish brown or dark brown....17

16*B*. Heartwood straw brown to roseate brown, characteristic odor.....WHITE CEDARS

17*A*. Wood fine textured, heartwood wine red, sapwood white, aromatic or peppery taste.....PENCIL OR RED CEDAR
VIRGINIA RED CEDAR
EASTERN RED CEDAR
SOUTHERN RED CEDAR

17*B*. Wood medium to coarse textured, heartwood reddish brown to dark brown, sometimes with lavender tinge, light in weight, without peppery taste, never "pecky"[1] .....WESTERN RED CEDAR

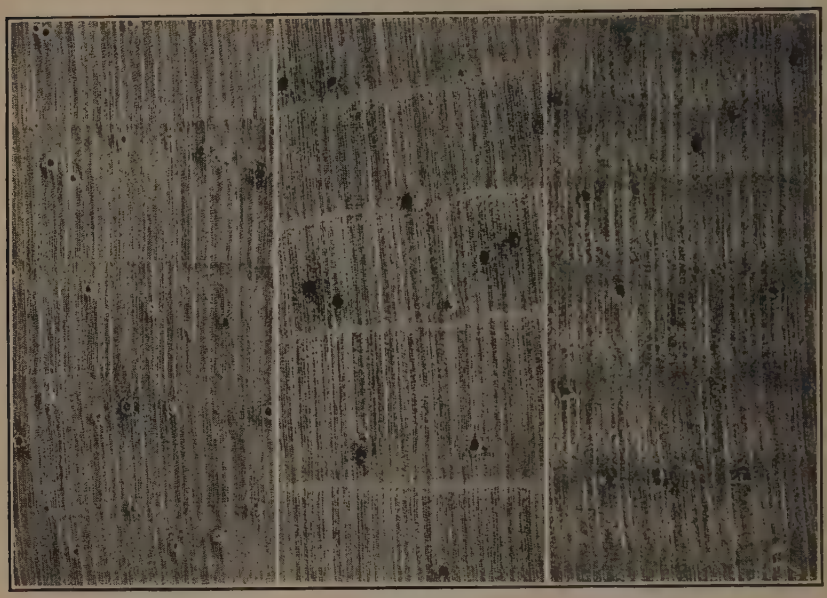
[1] "Peckiness" is a peculiar type of decay common to incense cedar and cypress and appears in the wood as small decayed areas in which the substance becomes brittle before it finally becomes powdery and disappears. The borders of these decayed areas are sharply defined, while the wood outside them is in no way injured; consequently, such a form of decay may be considered as injuring the strength of the timber only, as it eliminates a certain volume of the tissue. It does not affect its durability. These infected areas vary in size, commonly occurring from ¼ to 1¼ in. in diameter and from ¼ to 1½ in. in length (see Fig. 33).

Forsaith, C. C., "The Technology of New York State Timbers," *N. Y. State Coll. Forestry*, Syracuse, N. Y., *Tech. Pub.* 18, p. 278, September, 1926.

(Courtesy Forest Products Laboratory.)

FIG. 33.—A cross-section of Southern Cypress showing "peck." This photograph was made from a section of a Cypress post which has given many years of service.

Softwoods



Northern White Pine | Sugar Pine | California White Pine and Pondosa Pine

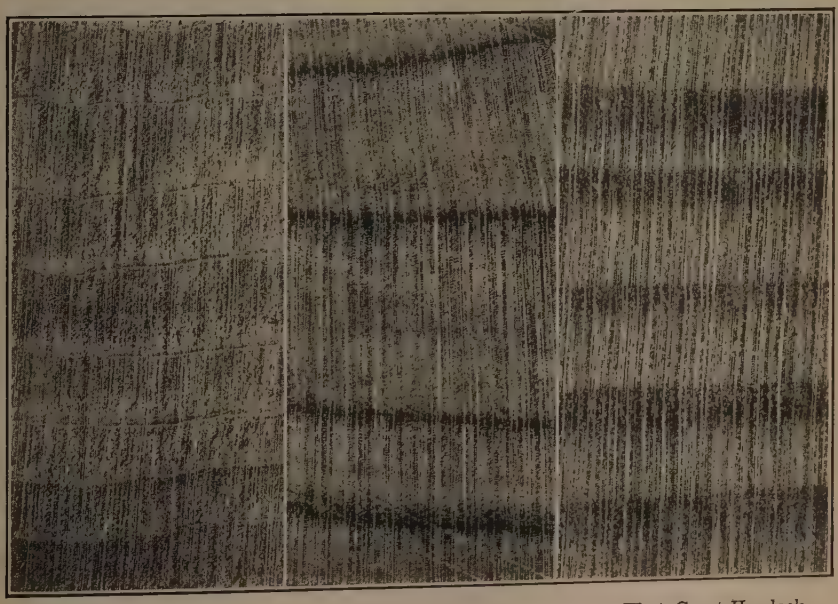
Longleaf Pine | Sitka Spruce | Douglas Fir

(*Courtesy Forest Products Laboratory.*)

FIG. 34.—Non-porous woods. (All cross-sections magnified 7.5 diameters.)

Softwoods

Tamarack Southern Cypress Southern White Cedar



Northern White Cedar Eastern Hemlock West Coast Hemlock

(Courtesy Forest Products Laboratory.)

FIG. 35.—Non-porous woods. (Cross-section magnified 7.5 diameters.)

List of Softwoods

With Commercial Names of Lumber as Described in the Key

Commercial name of lumber	Common name of tree	Botanical name of tree	Key number
Northern white pine	Northern white pine	*Pinus strobus*	4*A*
(Also known as Canadian white pine, eastern white pine, Minnesota white pine, northern pine, soft-cork white pine, soft white pine, white pine, Wisconsin white pine)			
Sugar pine	Sugar pine	*Pinus lambertiana*	5*A*
(Also known as California sugar pine)			
Idaho white pine	Western white pine	*Pinus monticolo*	5*B*
(Also known as white pine, soft Idaho white pine)			
California white pine and Pondosa pine	Western yellow pine	*Pinus ponderosa*	6*A*
(Also known as Arizona soft pine, Oregon white pine, Oregon pine, western pine, western white pine)	Jeffrey pine	*Pinus jeffreyi*[1]	
Southern pine			6*B*
Longleaf pine	Longleaf pine	*Pinus palustris*	7*B*
(Also known as Florida longleaf yellow pine, Georgia yellow pine, longleaf yellow pine, southern pine, southern yellow pine, yellow pine)			
Pitch pine	Pitch pine	*Pinus rigida*	
(Also known as southern pine, southern yellow pine)			
Pond pine	Pond pine	*Pinus rigida serotina*	
(Also known as southern pine, southern yellow pine)			
Slash pine	Slash pine	*Pinus caribaea*	
(Also known as southern pine, southern yellow pine)			
Spruce pine	Spruce pine	*Pinus glabra*	
(Also known as southern pine, southern white pine, southern yellow pine)			
Arkansas soft pine	Virginia pine	*Pinus virginiana*	
North Carolina pine			
Virginia pine			
(Also known as North Carolina pine, spruce pine)			
Shortleaf pine	Shortleaf pine	*Pinus echinata*	8*A*
(Also known as Arkansas shortleaf pine, Arkansas soft pine, North Carolina pine, shortleaved yellow pine, southern yellow pine, southern pine)			
Loblolly pine	Loblolly pine	*Pinus taeda*	8*B*
(Also known as Arkansas soft pine, North Carolina pine, southern pine, southern yellow pine, Virginia pine)			
Eastern spruces			10*A*
Red spruce	Red spruce	*Picea rubra*	
(Also known as Adirondack spruce, Canadian spruce, West Virginia spruce)			
White spruce	White spruce	*Picea glauca*	
(Also known as Adirondack spruce, Canadian spruce)			
Black spruce	Black spruce	*Picea mariana*	

[1] Usually marketed with California white pine, which it closely resembles.

LIST OF SOFTWOODS.—(*Continued*)

With Commercial Names of Lumber as Described in the Key

Commercial name of lumber	Common name of tree	Botanical name of tree	Key number
Sitka spruce	Sitka spruce	*Picea sitchensis*	10*B*
(Also known as sequoia silver spruce, silver spruce, spruce, West Coast spruce, Western sitka spruce, yellow spruce)			
Douglas fir	Douglas fir	*Pseudotsuga taxifolia*	11*A*
(Also known as Red fir (Rocky Mountain type) Douglas yellow fir, fir, goldenrod, Douglas fir, Montana fir, national yellow fir, Oregon fir, Oregon pine, Pacific Coast Douglas fir, "Santian" quality fir, yellow Douglas fir, yellow fir)			
Tamarack	Eastern tamarack	*Larix laricina*	11*B*
Western larch	Western larch	*Larix occidentalis*	11*B*
(Also known as larch, Montana larch)			
Southern cypress	Southern cypress	*Taxodium distichum*	12*A*
(Also known as American bald cypress, black cypress, cypress, Gulf cypress, Gulf Coast red cypress, Gulf red cypress, Louisiana red cypress, red cypress, Tidewater red cypress, white cypress, yellow cypress)	Pond cypress	*Taxodium adscendens*	
Redwood	Redwood	*Sequoia sempervirens*	14*A*
Eastern hemlock	Eastern hemlock	*Tsuga canadensis*	15*A*
(Also known as hemlock, Huron pine, Pennsylvania hemlock, Pennsylvania white hemlock, West Virginia hemlock, Wisconsin white hemlock)			
West Coast hemlock	Western hemlock	*Tsuga heterophylla*	15*B*
(Also known as hemlock, Pacific Coast hemlock, Pacific hemlock, Pacific (western) hemlock, Western hemlock)			
Cedars			
Northern white cedar	Northern white cedar	*Thuja occidentalis*	16*B*
(Also known as Michigan white cedar, New Brunswick cedar, white cedar)			
Southern white cedar	Southern white cedar	*Chamaecyparis thyoides*	
(Also known as white cedar ("juniper")			
Eastern red cedar	Eastern red cedar	*Juniperus virginiana*	17*A*
(Also known as Tennessee red cedar)	Southern red cedar	*Juniperus lucayana*	
Western red cedar	Western red cedar	*Thuja plicata*	17*B*
(Also known as cedar, red cedar pine, Washington red cedar)			

Hardwood Key[1]

B. Wood with pores (vessels).....18
The pores are conspicuously larger than the surrounding cells, although in some species they are not visible without magnification. Neither the pores nor other cells are in continuous radial rows.

18*A*. Woods which are ring porous; that is, the pores at the beginning of each annual ring are comparatively large, forming a distinct porous ring, and decrease in size more or less abruptly toward the summerwood.....19

18*B*. Woods which are diffuse porous; that is the pores are of about uniform size and evenly distributed throughout the annual ring, or if they are slightly larger and more numerous in the springwood they gradually decrease in size and number toward the outer edge of the ring.....23

19*A*. Summerwood figured, with wavy or branched radial bands, the bands visible without a lens on smoothly cut surface.....20

19*B*. Summerwood figured, with long or wavy short tangential bands which include the pores, the bands visible without lens on smoothly cut end surfaces.....22

19*C*. Summerwood figured, with numerous fine, light-colored tangential lines (*parenchyma*) (see Fig. 36), which do not embrace the pores, pores in the summerwood not much smaller than those in the springwood, usually visible without a lens, lines of parenchyma conspicuous under lens, barely visible without a lens, heartwood reddish brown, sapwood white, wood heavy and very hard.....THE HICKORIES

20*A*. Many rays very broad and conspicuous, wood heavy to very heavy:.....THE OAKS[2].....21

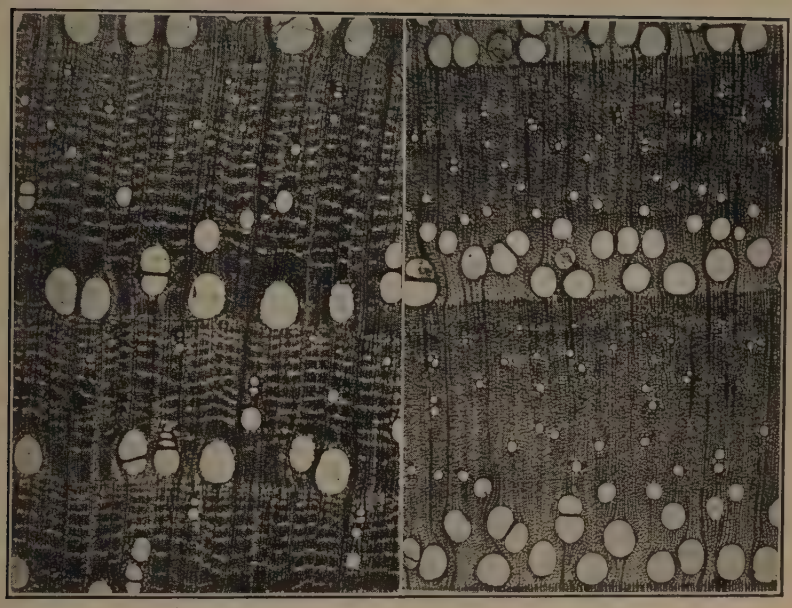
20*B*. All rays very fine and inconspicuous, color grayish brown, wood moderately light, easily worked.....CHESTNUT

21*A*. Pores in the summerwood are so small and so numerous as to be exceedingly difficult to count under lens, pores in the springwood of the heartwood usually densely plugged with tyloses, heartwood brown without reddish tinge
.....THE WHITE OAKS

21*B*. Pores in summerwood large, distinctly visible with (sometimes without) a hand lens, and not so numerous but that they can be readily counted under a lens, pores in springwood of the heartwood mostly open, tyloses not abundant, heartwood brown with reddish tinge, especially in vicinity of knots
.....THE RED OAKS

[1] See Figs. 37, 38, 41 and 42.

[2] For further identification of the oaks, see p. 171.



A *B*

(*Courtesy Forest Products Laboratory.*)

FIG. 36.—*A*—Cross-section of Shagbark Hickory, *B*—Cross-section of White Ash showing typical parenchyma tissue. Magnified 20 diameters.

22*A*. Careful examination with a hand lens shows the pores of the summerwood to be joined in more or less continuous bands and the bands to be evenly distributed throughout the summerwood, sapwood moderate in width or narrow, mostly less than 3 in., heartwood distinct, light to deep reddish brown, rays not distinct without a lens .....THE ELMS

22*B*. Careful examination with a hand lens shows the pores of the summerwood to be isolated or in radial rows of two or three but surrounded by parenchyma in such a manner as to appear in wavy tangential bands, usually more distinct without a lens than with one, parenchyma projecting tangentially from the pores in comparatively long lines, often joining pores widely separated, sapwood several inches wide, heartwood grayish brown or silvery brown, occasionally with reddish tinge, wood heavy and hard .....THE ASHES

23*A*. Rays comparatively broad and conspicuous, the widest ones fully twice as wide as the largest pores, appearing on the radial surface as distinct "flakes" of silver grain similar to quartered oak, only finer, color in various shades of light reddish brown..24

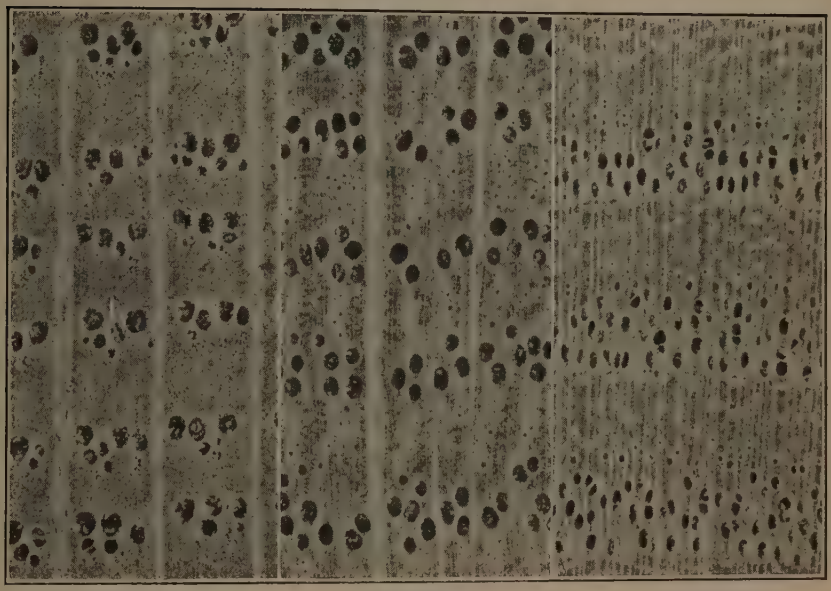
23*B*. Rays narrower, but very distinct without a lens, the widest ones about the same width as the largest pores.....25

23*C*. Rays comparatively fine, narrower than the pores.....26

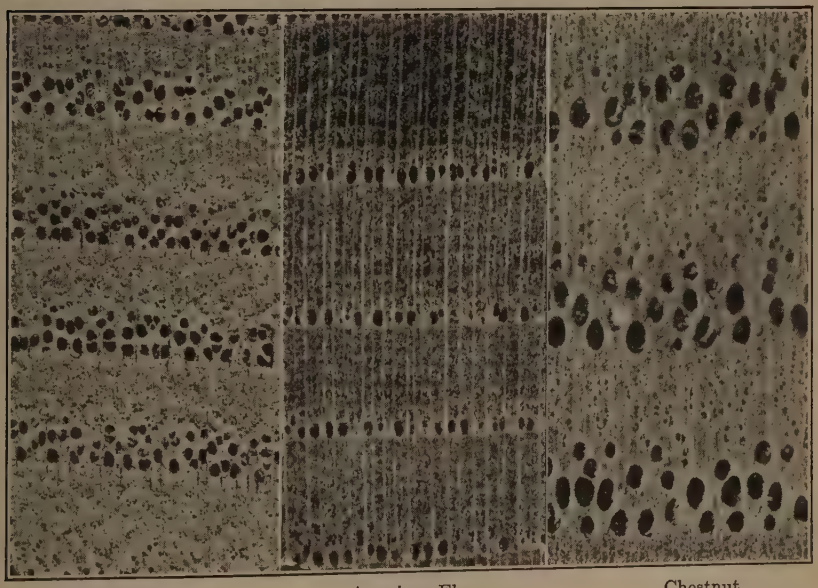
24*A*. Practically all rays broad, pores crowded, decreasing little if any in size at the extreme outer edge of the annual ring, moderately heavy, light-pink color, when quartered wood ray is very apparent and striking.....SYCAMORE

24*B*. Only part of the rays broad, separated by numerous narrow ones, the others narrower than the largest pores; pores crowded in the springwood, decreasing in size and number toward the outer edge of annual ring, thereby giving rise to a harder and darker band of summerwood, wood usually fairly straight grained, heavy and hard, color light-pinkish cast..... BEECH

(*Hardwoods*)



White Oak Red Oak White Ash



Slippery Elm American Elm Chestnut

(*Courtesy Forest Products Laboratory.*)

FIG. 37.—Ring-porous woods. (All cross-sections magnified 7.5 diameters.)

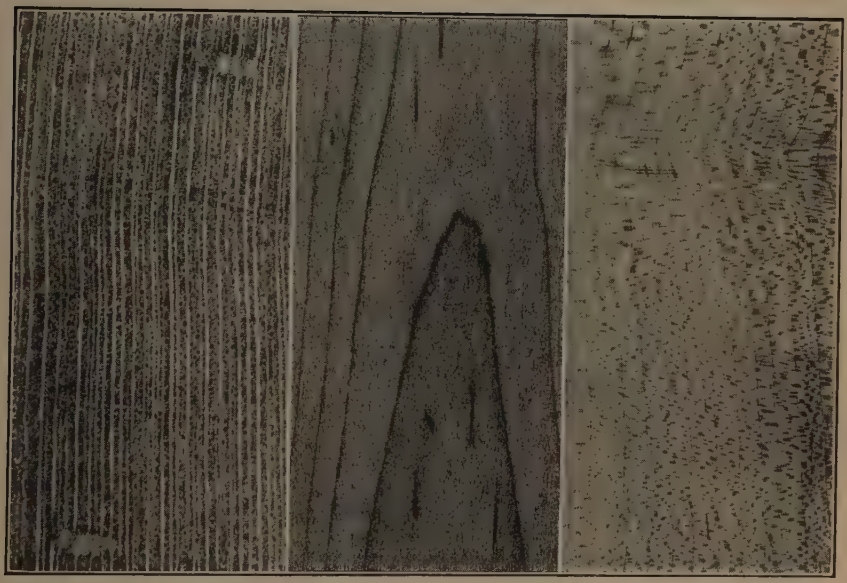
(*Hardwoods*)

Sycamore Beech Sugar Maple

Black Cherry Mahogany Tanguile

(*Courtesy Forest Products Laboratory.*)

FIG. 38.—Diffuse-porous woods. (All cross-sections magnified 7.5 diameters.)



A B C

(*Courtesy Forest Products Laboratory.*)

FIG. 39.—*A*—Cross-section, *B*—Tangential section, *C*—Radial section of Red Maple showing pith flecks. In the natural wood they appear as dark discolorations. All magnified 7.5 times.

25*A*. Color of heartwood light brown to reddish tinge, sapwood white, wood medium hard to hard, springwood and summerwood of uniform density, sapwood wide ..... THE MAPLES

25*B*. Color of heartwood reddish brown, springwood slightly more porous than summerwood, sapwood narrow, pith flecks[1] and gum pockets[2] common, wood moderately heavy ..... BLACK CHERRY

26*A*. Ripple marks[3] not present on tangential surface 27

26*B*. Ripple marks present on tangential surface, heartwood salmon to deep reddish brown, pores rather large, uniform in size and distribution, often filled with dark amber-colored gum, growth rings not always present ..... MAHOGANY

27*A*. Pores visible without a lens 28

27*B*. Pores not visible without a lens 29

28*A*. Wood heavy and hard, heartwood chocolate brown, pores comparatively large and conspicuous without a lens, decreasing in size toward the outer limit of each annual ring, not crowded, fine tangential lines of parenchyma often visible between pores ..... BLACK WALNUT

28*B*. Wood moderately light and soft, heartwood light chestnut brown, pores somewhat smaller, decreasing in size toward outer limit of annual ring ..... BUTTERNUT

29*A*. Pores appearing comparatively large and conspicuous under a lens 30

29*B*. Pores appearing comparatively small under a lens 31

30*A*. Pores not crowded, decreasing little if any in size toward the outer limit of the annual ring, rays distinct under a lens, heartwood pale to moderately deep reddish brown, wood soft to hard: ..... THE BIRCHES

30*B*. Pores crowded, decreasing in size and number toward the outer limit of each annual ring, rays very fine, barely visible without a lens, pith flecks occasionally present but not abundant, wood light and soft, color white to light grayish brown ..... COTTONWOOD

[1] A pith fleck is a narrow streak, usually brownish up to several inches in length on the face of a piece, resulting from the larvæ of an insect having burrowed in the growing tissue or cells of the tree (see Fig. 39).

[2] A gum spot or streak is an accumulation of gumlike substance occurring as a small patch or streak in the piece. It may occur in conjunction with a bird peck or other injuries to the growing tree.

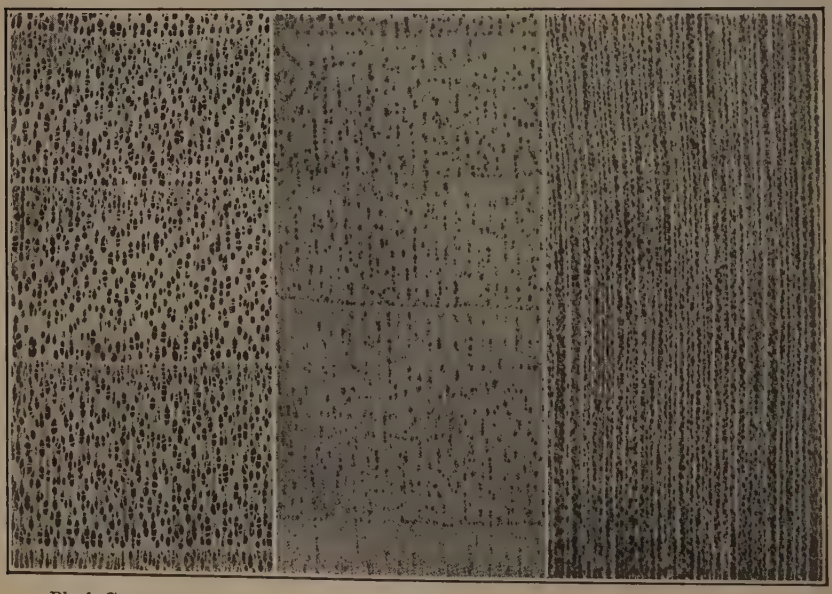
[3] There are numerous woods which show on longitudinal section (particularly the tangential) fine, delicate cross-lines of stripes, sometimes called *ripple marks*. There are three species in particular which have wavy ripple marks: mahogany, persimmon, and Ohio buckeye (see Fig. 40).

(Courtesy Forest Products Laboratory.)

FIG. 40.—Tangential surface of True Mahogany showing the Rays more or less in horizontal rows or stories. (Natural size.)

(*Hardwoods*)

Black Walnut Butternut Yellow Birch



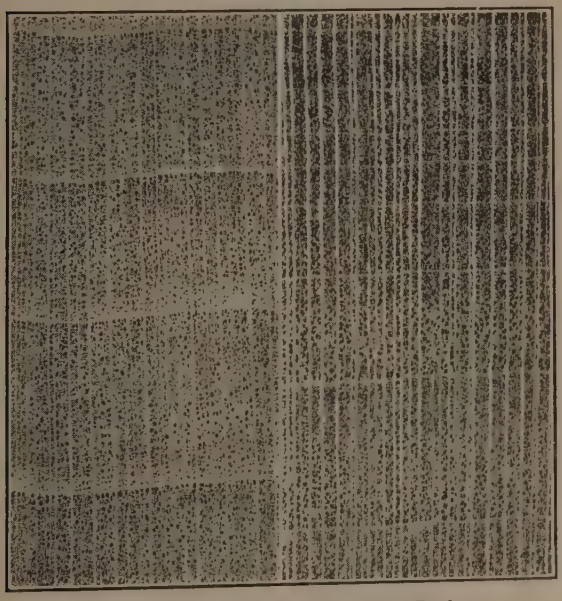
Black Cottonwood Tupelo Red Gum

(*Courtesy Forest Products Laboratory.*)

FIG. 41.—Diffuse-porous woods. (All cross-sections magnified 7.5 diameters.)

31*A*. Rays fairly distinct under lens.....32
31*B*. Rays indistinct even under a hand lens, wood rather moderately heavy, tough but not strong, tendency towards cross-grain, pores small and crowded, heartwood grayish, sapwood nearly white, annual ring indistinct:.....TUPELO[1]
32*A*. Heartwood light yellow to white.....33
32*B*. Heartwood reddish brown, rays very fine yet distinct under lens and close together, pores crowded, wood moderately heavy, sapwood pinkish white (sapwood sold commercially as *sap gum*). . . . . RED GUM
33*A*. Heartwood yellowish brown with a greenish tinge, rays distinct without a lens, wood moderately light, annual ring appears on smooth, clear-cut cross-section as terminating in white band, wood moderately soft, easily worked.....YELLOW POPLAR
33*B*. Heartwood creamy white, rays visible without a lens, not in tiers, wood very light and soft, black streaks common, wood has characteristic odor when wet.....BASSWOOD

(*Hardwoods*)



Basswood Yellow Poplar

(*Courtesy Forest Products Laboratory.*)

FIG. 42.—Diffuse-porous woods. (Cross-sections magnified 7.5 diameters.)

[1] In the trade, black gum (*Nyssa sylvatica*) is frequently mixed in shipments with tupelo. Identification of these two species is difficult, and actual distinction can be determined only by comparison with a piece of wood known to be one species or the other. Knowledge of regional habitat will aid materially.

List of Hardwoods

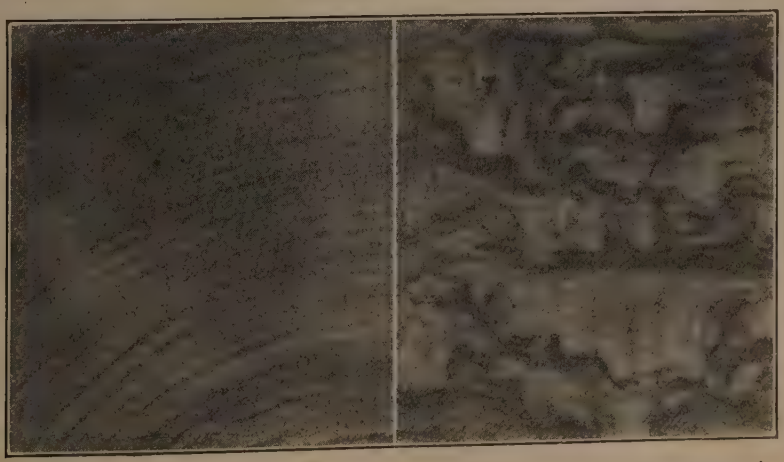
With Commercial Names of Lumber as Described in the Key

Commercial name of lumber	Common name of tre	Botanical name of tree	Key number
The hickories	.....	.....	19*C*
Hickory	Bigleaf shagbark hickory	*Hicoria laciniosa*	
	Bitternut hickory	*Hicoria cordiformis*	
	Mockernut hickory	*Hicoria alba*	
	Pignut hickory	*Hicoria glabra*	
	Shagbark hickory	*Hicoria ovata*	
The oaks	.....	.....	20*A*
Chestnut	Chestnut	*Castenea dentata*	20*B*
White oak	White oak (also known as—forked-leaf white oak, West Virginia soft white oak)	*Quercus alba*	21*A*
	Bur oak	*Quercus macrocarpa*	
	Chestnut oak	*Quercus montana* (=*Q. prinus*)	
	Chinquapin oak	*Quercus muehlenbergii*	
	Overcup oak	*Quercus lyrata*	
	Post oak	*Quercus stellata*	
	Swamp chestnut oak	*Quercus prinus* (=*Q. michauxii*)	
	Swamp white oak	*Quercus bicolor*	
Red oak	Red oak (also known as West Virginia soft red oak)	*Quercus borealis maxima* (= Q. *rubra* Auth's not L)	21*B*
	Black oak	*Quercus velutina*	
	Pin oak	*Quercus palustris*	
	Southern red oak	*Quercus rubra* (= Q. *digitata*)	
	Swamp red oak	*Quercus rubra pagodaefolia*	
	Texas red oak	*Quercus texana*	
	Water oak	*Quercus nigra*	
	Willow oak	*Quercus phellos*	
The elms	.....	.....	22*A*
Soft elm	American elm	*Ulmus americana*	
Gray elm	Slippery elm	*Ulmus fulva*	
Rock elm	Rock elm	*Ulmus racemosa*	
The ashes	.....	.....	22*B*
Black ash (Also known as brown ash, ash (black or brown)	Black ash	*Fraxinus nigra*	
White ash	Blue ash	*Fraxinus quadrangulata*	
	Green ash	*Fraxinus pennsylvanica lanceolata*	
	Red ash	*Fraxinus pennsylvanica*	
	White ash	*Fraxinus americana*	
	Biltmore white ash	*Fraxinus biltmoreana*	
	Oregon ash	*Fraxinus oregona*	
Sycamore	Sycamore	*Platanus occidentalis*	24*A*
Beech	Beech	*Fagus grandifolia* (= F. *atropunicea*)	24*B*
The maples	.....	.....	25*A*
Hard maple (Also known as—Maple; sapwood graded as "White maple")	Sugar maple	*Acer saccharum*	
	Black maple	*Acer nigrum*	
Soft maple	Red maple	*Acer rubrum*	
	Silver maple	*Acer saccharinum*	
Cherry	Black cherry	*Prunus serotina*	25*B*

LIST OF HARDWOODS.—(*Continued*)

With Commercial Names of Lumber as Described in the Key

Commercial name of lumber	Common name of tree	Botanical name of tree	Key number
Mahogany (Also known as Costa Rica mahogany, Cuban mahogany, Guatemalan mahogany, Honduras mahogany, Mexican mahogany, San Domingo mahogany)	Mahogany	*Swietenia mahogoni* and other species	26*B*
Walnut (Also known as American walnut)	Black walnut	*Juglans nigra*	28*A*
Butternut (Also known as American white walnut, butternut, lemon walnut, oil nut, white walnut)	Butternut	*Juglans cinerea*	28*B*
The birches			30*A*
Birch	Yellow birch (heartwood of yellow birch sold as red birch)	*Betula lutea*	
	Sweet birch	*Betula lenta*	
	River birch	*Betula nigra*	
	Paper birch	*Betula papyrifera*	
Cottonwood	Eastern cottonwood	*Populus deltoides*	30*B*
	Black cottonwood	*Populus trichocarpa*	
Tupelo	Tupelo gum	*Nyssa aquatica*	31*B*
Red gum (Also known as delta red gum) The sap wood of red gum is usually sold as sap gum	Red gum (Also known as satin walnut, hazel pine (England), figured red gum (see Fig. 43)	*Liquidambar styraciflua*	32*B*
Sap gum	Red gum (Sapwood only).	*Liquidambar styraciflua*	32*B*
Yellow poplar (Also known as poplar, soft yellow poplar, whitewood)	Yellow poplar	*Liriodendron tulipifera*	33*A*
Basswood	Basswood	*Tilia glabra* (*T. americana*)	33*B*
	White basswood	*Tilia heterophylla*	



(*Courtesy Forest Products Laboratory.*)

FIG. 43.—*Left*—Cross-section of Plain Red Gum, *Right*—Cross-section of Figured Red Gum, natural size, showing the irregular structure of infiltrated deposits in the wood, which produce the characteristic figure in Red Gum.

Additional Identifying Features of Non-porous Woods (Softwoods).—Spruce can be easily confused with the soft pines but can be identified by the absence of a reddish tinge in the heartwood and the fact that the resin ducts are small and scattered and inconspicuous as compared with those in pine. Spruce has a decided silvery sheen and is light, soft, and easy to work.

In the lumber yard, hemlock is usually recognized by its color. The eastern species is light buff with a reddish-brown tinge, while the wood of the western species is a decided pink. The surfaces of both species of hemlock have a characteristic slivery appearance, and the wood has a tendency toward "shakiness." The West Coast hemlock is the more even grained, and seasonal zones are generally uniform in width.

The light-straw color, combined with great lightness and softness, distinguishes the white pines and sugar pine from the hard pines (all others in the market); they may also be recognized by the gradual change of springwood into summerwood. This change in hard pines is abrupt, making the summerwood appear as a sharply defined or broad band. The Norway pine is somewhat lighter and softer than the soft, shortleaf pine. The annual ring is more sharply defined than in the heavier white pine, and the wood is heavier and harder. The longleaf pine is structurally heavy, hard, and resinous and has narrow rings, showing little sapwood and differing in this respect from the shortleaf pine and loblolly pine, which usually have wide rings and more sapwood.

This means of identification, however, will not apply in every instance, inasmuch as there are variations in the width of rings between the species. These variations are due directly to environmental factors, such as soil conditions, spacing, and so forth.

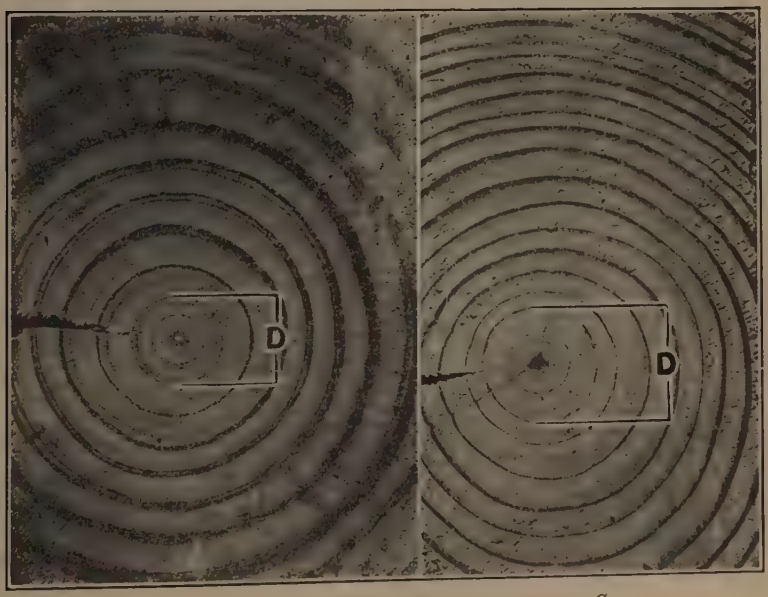
The Identification of Douglas Fir

Douglas fir is a resinous wood, with a characteristic sweetish odor. Exudations of resin on end and side surfaces and pitch pockets are common. Occasionally, pitch streaks occur. The sapwood, which is from 1 to 3 in. wide, is white. The freshly cut heartwood is light reddish yellow in color. On exposure to light and air it becomes distinctly reddish, sometimes cherry red, or reddish brown, except the outer portion of old trees, which often remains light reddish yellow, which explains why the wood is sometimes known as *yellow fir*. The summerwood is pronounced, except in very narrow rings such as usually occur in the outer portion of old trees.

Under the microscope, Douglas fir can easily be distinguished from other structural softwoods by the fine spiral thickenings on the inner side of the cell walls, similar to the thread in a nut.

The other softwoods can be distinguished from Douglas fir by the following characteristics:

A



B C

(*Courtesy Forest Products Laboratory.*)

FIG. 44.—*A*—longleaf; *B*—loblolly; *C*—shortleaf pine of moderate growth, showing pith (the dark core in the center) and diameter of second annual ring, *D*. All natural size.

Southern pines, Norway pine, California white pine and pondosa pine: heartwood less reddish and more orange brown, characteristic pine-pitch odor; on planed surfaces the resin duct often are pronounced as brownish lines running parallel to the grain, whereas in Douglas fir the resin ducts are more obscure.

Eastern hemlock, West Coast hemlock, and balsam firs: no pronounced difference in color of heartwood and sapwood, as in Douglas fir; exudations of resin; pitch pockets; pitch streaks absent; odor not pronounced.

Sitka spruce: color of heartwood pale pinkish brown, split or dressed surfaces have a silky sheen, tangentially split or dressed surfaces have a "dimpled" or bird's-eyed appearance; odor not pronounced.

Western larch: russet-brown color, odor not pronounced.

Method of Distinguishing Longleaf from Loblolly and Shortleaf Pine

In the examination of specimens of wood from the southern pines, a distinct difference was noted in the size of the pith of longleaf pine and that of shortleaf and loblolly pine. This difference suggests an easy method of distinguishing pines, which will be particularly helpful to the user because it does not require a microscope. Obviously, this method can be used only on timbers cut from the center of the tree; but as a rule it is only regarding large pieces that the engineer or contractor desires to know the exact species.

The pith is the small, dark, soft core at the center of the tree and averages larger in longleaf than in shortleaf or loblolly pine (see Fig. 44). In longleaf the pith is over 0.1 in. in diameter; in the other two species it usually is smaller, ordinarily about the size of the lead in a pencil, as in longleaf; but in vigorous trees it often is larger. The vigor of a tree at the time the pith was formed is indicated by the diameter of the second annual ring. Where, therefore, the pith in loblolly and shortleaf is over 0.1 in. in diameter, the diameter of the second annual ring is comparatively large; in fact, it is larger than in longleaf having the same-sized pith.

How to Use the Pith and Second Annual Ring for Identification

1. With a sharp knife carefully smooth the end surface of the pith and surrounding wood. If the pith or second annual ring is not clear, moisten the smoothed surface. If knots are present near the pith, satisfactory measurements cannot be made, and the other end of the timber should be inspected.
2. If the pith is about the size of the lead in an ordinary lead pencil or smaller, the specimen is not longleaf, and no further measurement is necessary.
3. If the pith is plainly over 0.1 in. in diameter, and the growth rings surrounding it are very narrow, the specimen is longleaf.

4. If in doubt as to the species, carefully measure the average diameter of the pith, not including small projections, using a rule graduated in twenty-fifths or fiftieths of an inch. The first and second rings are usually distinct, but in some pieces the first annual ring is faint, and care must be taken not to mistake the third annual ring for the second; sometimes false rings are present, but these can always be recognized by the fact that they are not prominent all the way around, and their outer limit is not defined by a sharp line.

5. On the diagram in Fig. 45 find the point where the vertical line, which indicates the diameter of the pith, intersects the horizontal line which indicates the diameter of the second annual ring.

6. If the point of intersection falls above the diagonal line in the diagram, the specimen is longleaf or, in rare instances, slash or pond pine. If it falls below the line, the specimen is not longleaf, but shortleaf, loblolly, or some other of the minor southern pines.

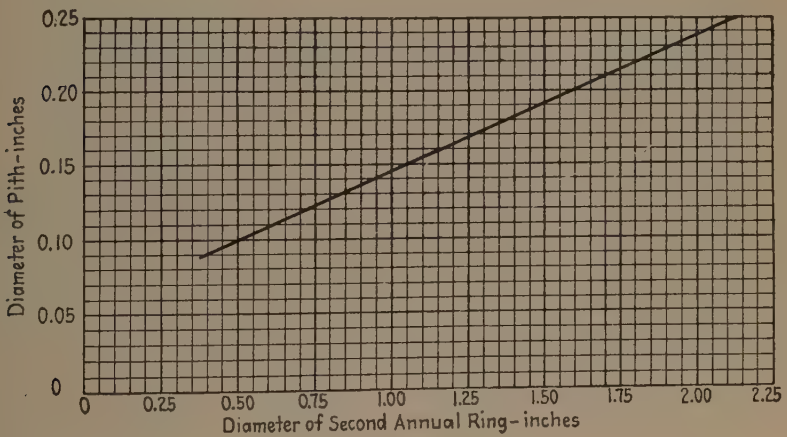


FIG. 45.

Additional Identifying Features of Ring-porous Woods (Hardwoods). Over 50 species of native oaks assume the proportions of trees, and about 25 are used for lumber. After the oaks are cut into lumber, there is no means known to the United States Forest Products Laboratory by which they can be identified as to exact species. By examination of the wood, however, it is easy to separate the oaks into two groups—the white oaks and the red oaks—and for most purposes, fortunately, it is not necessary to classify them any further. The oaks all average about the same in strength, but those in the white-oak group are much more durable under conditions favorable to decay than those in the red-oak group.

The white-oak group includes true white oak, swamp white oak, bur oak, post oak, overcup oak, chestnut oak, and swamp chestnut oak. The

red-oak group includes true red oak, southern red oak, black oak, scarlet oak, Texan oak, blackjack oak, water oak, willow oak, and laurel oak.

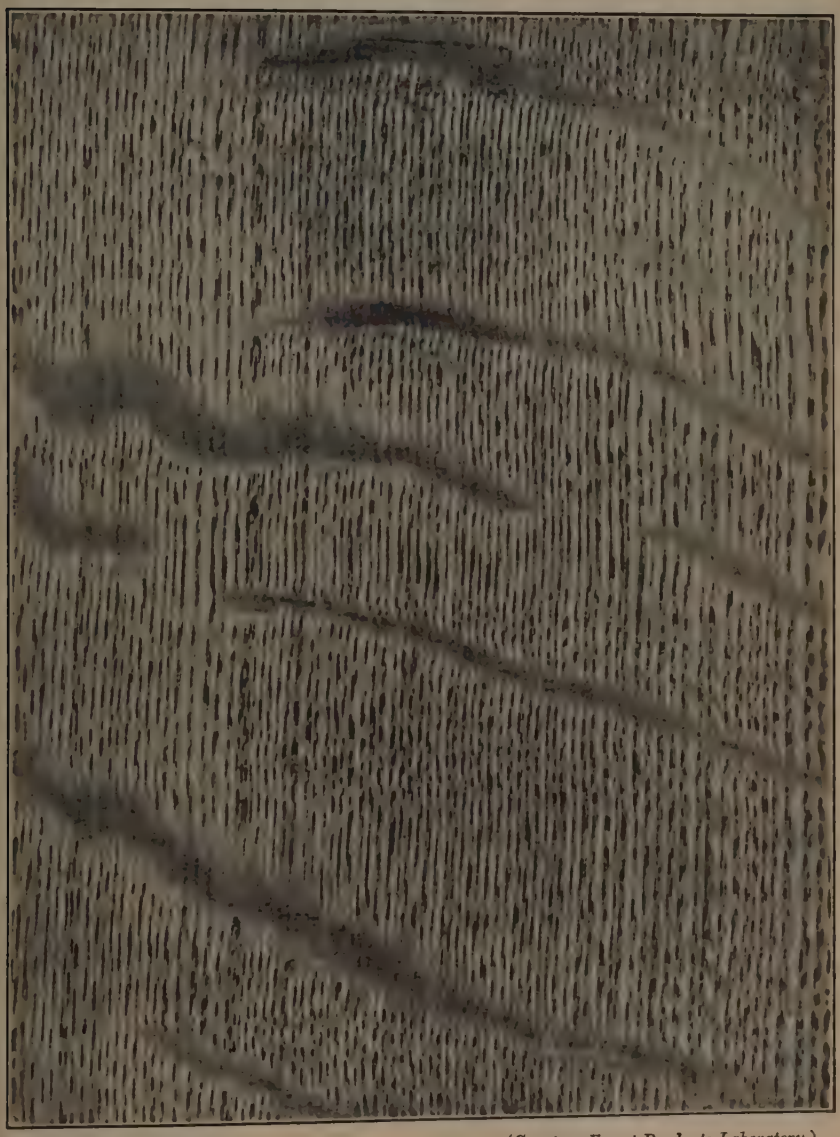
The color of the wood is a ready but not absolutely reliable means of distinguishing the white oaks from the red oaks. Red oaks usually have a distinctly reddish tinge, especially near the knots. The wood of the

(*Courtesy Forest Products Laboratory.*)

FIG. 46.—A cross-section of White Oak, magnified 20 diameters showing tyloses in the pores of the wood in the form of irregular shaped films or obstructions. In some instances they appear as tiny threads.

white oaks is generally a grayish brown, but occasionally a reddish tinge is found in white-oak lumber.

For more accurate identification it is necessary to examine the pores of the wood. These will be found as tiny holes on a smoothly cut end surface, the largest being visible to the unaided eye. They are not of uniform size throughout each growth ring but are considerably larger in the wood formed in the spring, decreasing in size rather abruptly toward the summerwood. The large pores in the springwood of the heartwood and inner sapwood of the white oaks are usually plugged up with a froth-



(Courtesy Forest Products Laboratory.)

FIG. 47.—A radial section of White Oak, photographed natural size, showing characteristic wood, or medullary rays, extending across its surface.

like growth called *tyloses*(see Fig. 46), and those of the red oaks are open. This feature, however, is not so reliable for classification as the character of the much smaller pores in the summerwood.

To be certain whether a piece of oak belongs to the white- or the red-oak group, cut the end grain smoothly with a sharp knife across several growth rings of average width. With the aid of a hand lens examine the small pores in the dense summerwood. If the pores in this part of the growth ring are plainly visible as minute rounded openings and are not so crowded but that they can be readily counted, the wood belongs to the red-oak group. If the pores in the summerwood are very small, somewhat angular, and so numerous that it would be exceedingly difficult to count them, the wood belongs to the white-oak group.

The ashes, elms, hickories, and oaks may, on casual observation, appear to resemble each other, on account of the pronounced zone of porous springwood. In the species noted above, as well as others, the pores in these woods are scattered among the fibers and are of comparatively large diameter, have open ends, and form continuous tubes or pores. Technically, these pores are known as *vessels* and serve to conduct sap from the roots to the leaves. The conifers do not have such pores, but the sap in traveling from one fiber to another must pass through the fiber walls. In coarse-textured woods or so-called *open-grained woods*, such as oak, ash, etc., some of the pores are plainly visible to the unaided eye, appearing as minute holes on the cross-section and fine grooves on the larger longitudinal surface. Wood rays are commonly known as *medullary rays*, pith rays, or ray flecks and appear in radial sections as irregular-shaped areas varying in size, with a decided sheen, extremely smooth, and apparently void of any evidence of pores or vessels. In oak these ray flecks are extremely pronounced and produce what is known as the *quartered* effect of quartered-oak lumber, as shown in Fig. 47. In the cross-section of a piece of freshly cut elm there will appear wavy lines of pores which are characteristic of this wood in the summerwood and appear as conspicuous, finely severed hatchings on the tangential sections. The ashes differ from the hickories by the conspicuously defined zone of springwood pores, which in hickory appear interrupted. The reddish hue of hickory, and the brown hue of the ash, may also distinguish them. In the oaks, the two groups can be readily distinguished by the manner in which the pores are distributed in the summerwood. In the white oaks the pores are fine and numerous and crowded in the summerwood, while in the black oaks and red oaks the pores are larger, fewer in number, and most isolated. The live oaks—as far as structure is concerned—belong to the black oaks but are diffuse-porous and are exceedingly heavy and hard.

The ashes all belong to the group of ring-porous hardwoods—that is, woods having one or more rows of large pores or cells formed at the

beginning of each year's growth or annual ring. The pores are much larger than the other cells of fibers which make up the annual ring, and their arrangement causes the appearance of conspicuous, concentric rings on the end grain of the log. The portion of each annual ring which contains the large pores is the springwood; and the denser, darker-colored portion, the summerwood.

Black ash is considerably lighter, softer, and weaker than any of the commercial white ashes—namely, the true white, green, blue, and Biltmore species.

Some of the differences between the two woods can be noted by ordinary inspection. The white ash tends to be heavier, the sapwood wider, with a grayish to reddish tinge, often pale heartwood, as compared with a plain brown, slightly olive color of heartwood in black ash.

Tyloses are almost always present and abundant in white ash, while absent or scattered in black ash.

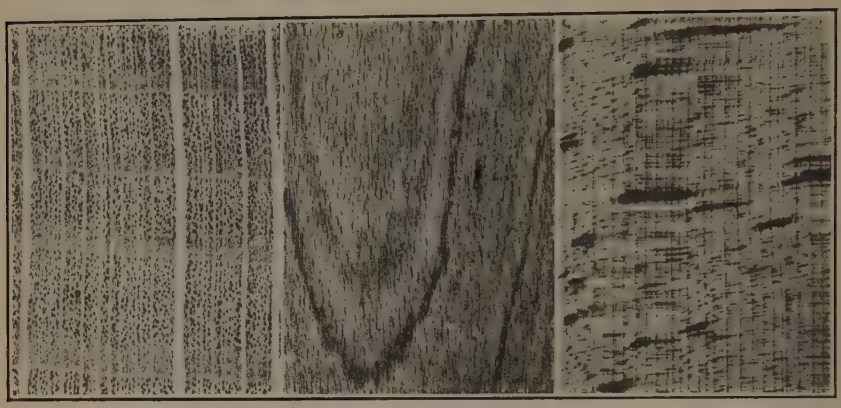
Additional Identifying Features of Diffuse-porous Woods (Hardwoods).—Cherry and birch are sometimes confused. The high pith rays of the cherry on radial sections readily distinguish it. Distinct pores of birch and springwood zone in cherry—as well as the darker reddish-brown color of the latter—will also prove helpful. Gum pockets and pith flecks are also characteristic of cherry (see p. 161).

Birch, beech, and maple look much alike, as shown in Fig. 48, and have approximately the same weight. Hence, it is easy to mistake one of them for another. A method which anyone can use to distinguish between them is suggested by the United States Forest Products Laboratory. This method makes use of the relative width of the pores and medullary rays in the three woods.

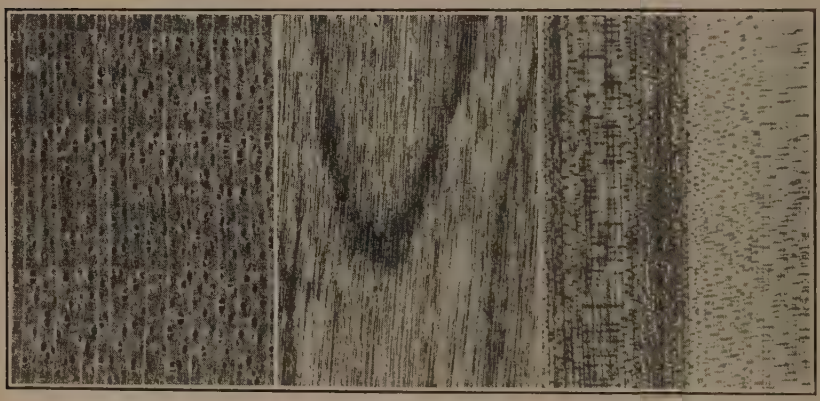
If the end grain of birch, beech, and maple is cut smooth with a sharp knife and examined with a hand lens, the pores will be seen as tiny holes distributed fairly evenly over the surface, and the medullary rays will appear as narrow lines of a different shade running at right angles to the growth rings. In beech, some of the rays are distinct even without a lens. The large rays are fully twice as wide as the largest pores. In maple, the rays are less distinct, and the largest are about the same width as the largest pores.

In birch, the rays are fine; invisible without a lens. The pores are several times larger than the rays, usually being visible to the unaided eye as minute holes on the end grain and as fine grooves on dressed faces of the board. The pores in birch are considerably larger than the pores in beech or maple.

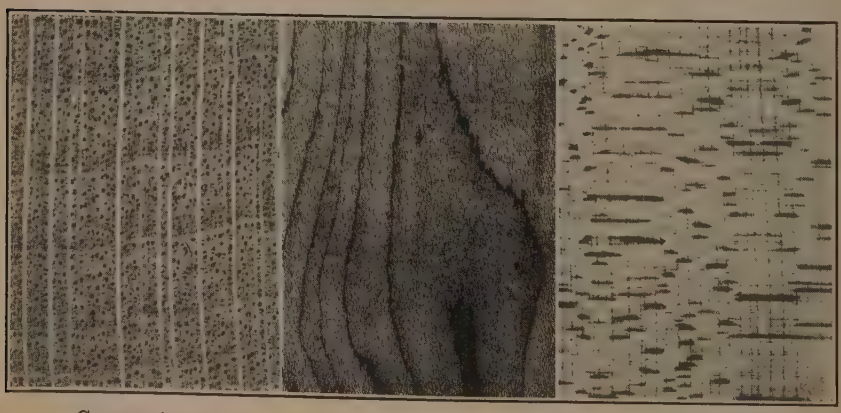
The appearance of the medullary rays on a "quartered" surface is also distinctive. Here they appear in beech as distinct "flakes," the largest being between $\frac{1}{16}$ to $\frac{1}{8}$ in. in height, when measured along the grain of the wood. In maple they are considerably smaller, rarely



Cross-section | Tangential section | Radial section
Beech



Cross-section | Tangential section | Radial section
Birch



Cross-section | Tangential section | Radial section
Sugar Maple

(*Courtesy Forest Products Laboratory.*)

FIG. 48.—(All sections magnified 7.5 diameters.)

attaining a height of 1/16 in. In birch they are comparatively inconspicuous.

Only true mahogany[1] from tropical America, Khaya (*African mahogany*), and certain Philippine hardwoods (*Philippine mahogany*)[2] have been commonly sold as mahogany in this country, but at various times over 60 different species of timber have been sold under that name. Although each of these species resembles the other in varying degrees, tropical-American mahogany and African mahogany possess one important characteristic in common, which is helpful in their identification. This is the occurrence of dark, amber-colored gum in many of the pores. The gum does not fill the pores but is recognized as dark specks or streaks in the pores as seen on smoothly cut end or side grain. It is barely visible to the naked eye but is easily seen through a hand lens with a magnification of 10 to 15 diameters.

Some other woods have similar dark masses of gum in the pores, but none of these is commonly substituted for mahogany. Among them are crabwood, and Sapeli, species imported from South America and Africa in small quantities only, and the Cedrelas (Spanish cedar, etc.), which are rarely sold as mahoganies and are easily recognized by their odor.

True mahogany has fine, continuous concentric lines on the cross-section, usually from 1/8 to 1/2 in. apart, which distinguish it from African mahogany, in which these lines are practically absent.

Philippine mahogany has none of the dark masses of gum in its pores. On smoothly cut end surfaces it shows broken tangential lines 1/8 in. to several inches apart, readily visible to the naked eye and appearing under a lens as rows of small openings filled with a white substance.

In the manufacture of furniture and cabinets a great deal of red gum is used as an imitation of mahogany or Circassian walnut. When red gum is properly finished it can be made to look so much like either of these woods that only by careful observation can the true be distinguished from the substitute. There is a distinct difference, however, between red gum and mahogany or walnut. This difference lies in the size of the pores.

In mahogany, Circassian walnut, and black walnut, the pores are so large that they can be seen distinctly on a smoothly cut surface of the end

[1] A more complete differentiation of mahogany and so-called mahogany, describing the common species in detail, may be found in *U. S. Dept. Agr. Bull.* 1050. "The Identification of True Mahogany, Certain So-called Mahoganies, and Some Common Substitutes." This may be obtained at a cost of 10 cts. (stamps not accepted) from the Superintendent of Documents, Government Printing Office, Washington, D. C.

[2] On July 15, 1926, the Federal Trade Commission prohibited "the advertisement or sale of hardwood lumber of the Philippine Islands, or any product made therefrom, as 'mahogany' or 'Philippine mahogany,' or under any name containing the word 'mahogany' unless such wood or lumber or the wood from which such products are made is derived from the trees of the mahogany or Meliacea family." This order was affirmed on May 14, 1928, by the United States Circuit Court of Appeals, Second Circuit, New York.

grain, where they appear as minute openings smaller than pinholes but visible without magnification. On surfaced faces the pores appear as fine grooves, running parallel with the grain. They are even visible through the varnish, appearing as dark lines.

In red gum the pores are much smaller and can be seen only with a magnifying glass.

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CHAPTER V

PRESERVATIVE TREATMENT

Wood preservation is a means of protecting timber from decay and thereby maintaining the original strength of the wood over a long period of time.

Decay is the result of the action of certain low forms of plant life called *fungi*, which consist of very fine, threadlike filaments that penetrate the wood in all directions. Certain substances in the wood constitute the food of the fungi, and as these substances are dissolved the structure is broken down until the wood reaches the condition commonly known as *rotten*.

The spores of the fungi are so small that they float long distances in the air, and when one drops upon a piece of wood where conditions are favorable, it germinates and the fungus begins its destructive action. Another way in which decay spreads is by fungi growing from one piece of wood to another.

The four requirements for the growth of the fungi that cause the decay of wood are air, moisture, a favorable temperature, and food. To prevent decay it is necessary to deprive the fungus of one or more of these four requirements. The wood itself supplies the food. It is out of the question in ordinary situations to remove air and warmth; and though moisture can sometimes be eliminated to a certain extent, this cannot be done when the wood is exposed to the weather. In general, therefore, the most effective method of preventing decay is to poison the food supply; and upon this principle is based the successful use of wood preservatives.

The preservation of wood has been practiced for centuries; but it was not until the early part of the nineteenth century that the preservation of wood by the injection of chemicals became scientific in principle. Many materials have been used and many methods tried to make wood resist decay, insects, and marine borers, and out of this wealth of experience, by the law of the survival of the fittest, a few preservatives have come into extensive use, while the majority of those suggested have fallen by the wayside.

WOOD PRESERVATIVES

A good wood preservative must be toxic to wood-destroying fungi, it must be suitable for penetrating the wood to the required depth, it should not weaken the timber or corrode metals, should stay in the wood, should

not be dangerous to handle, should be available in large quantities, and must be cheap. Coal-tar creosote and zinc chloride are the preservatives most widely used in the United States.

Coal-tar Creosote

Creosote, in the scientific sense, may be properly defined as any and all distillate oils boiling between 200 and 400° C., which are obtained by distillation from tars consisting principally of compounds belonging to the aromatic series and containing well-defined amounts of phenoloids.

Coal-tar creosote, because of its long, successful service, is the leading wood preservative for general use the world over. It is a black or brownish oil made by distilling coal tar. The first fractions collected in tar distillations are the light oils, and the residue is a pitch. In between is the portion which is saved for wood-preserving purposes. The character of the tar used, the extent to which the distillation is carried, and the portion of the distillate which is included in the creosote fraction govern the character of the creosote oil. The character of the various creosotes available, therefore, may vary to a considerable extent. Small differences in the creosote do not prevent it from giving good service, and satisfactory results in preventing decay may be expected from any reasonably good grade of coal-tar creosote.

The importance of coal-tar creosote to the wood-preserving industry is evidenced by the fact that the demand is usually greater than the supply. About 220,000,000 gal. of coal-tar creosote and its mixtures were used for treating wood in the United States in 1927.

Creosote Specifications.—Large consumers of creosote, or creosoted wood, usually purchase their creosote on specifications. This is the best way to insure the receipt of material of the desired quality and to have the quality the same in different shipments. The following specification of the American Wood-Preservers' Association is in common use and will give satisfactory results when properly applied. The Association also has other specifications.

American Wood-Preservers' Association Standard Specification for Grade 1 Creosote Oil for Ties and Structural Timber

1. The oil shall be a distillate of coal gas or coke-oven tar.[1] It shall comply with the following requirements:

2. It shall not contain more than 3 per cent of water.

3. It shall not contain more than 0.5 per cent of matter insoluble in benzol.

4. The specific gravity of the oil at 38° compared with water at 15.5° C. shall not be less than 1.03.

[1] Owing to the complexity of the chemical composition and physical properties of coal-tar creosote oil, and to the fact that some of the same compounds and properties which characterize coal-tar creosote are found in certain petroleum derivatives, the determination of the purity of creosote oil is difficult. When there is not certain

5. The distillate, based on water-free oil, shall be within the following limits:
Up to 210° C., not more than 5 per cent.
Up to 235° C., not more than 25 per cent.

6. The residue above 355° C., if it exceeds 5 per cent, shall have a float test of not more than 50 sec. at 70° C.

7. The oil shall yield not more than 2 per cent coke residue.

8. The foregoing tests shall be made in accordance with the standard methods of the American Wood-Preservers' Association.

Zinc Chloride

Zinc chloride is the standard water-soluble wood preservative in general use in the United States. The normal consumption for wood treatment is about 25,000,000 lb. annually. Zinc chloride is shipped either in the solid (fused) form or in concentrated solutions. When the freight haul is not too great, the concentrated solution, usually about 50 per cent strength, is shipped in drums or tank cars. For long freight hauls, the salt is shipped in solid form in airtight drums. For use in treating wood, a water solution of 2 to 5 per cent is prepared from the concentrated material.

The following specification for zinc chloride, adopted by the American Wood-Preservers' Association, is the one generally used in the purchase of zinc chloride for wood preserving purposes:

The zinc chloride shall be acid free and shall not contain more than 0.1 per cent iron. Fused or solid zinc chloride shall contain at least 94 per cent chloride of zinc. Concentrated zinc-chloride solution shall contain at least 50 per cent chloride of zinc.

Other Materials

Crude or semirefined petroleum is not toxic to wood-destroying fungi and hence by itself has no value as a wood preservative. Mixtures of coal-tar creosote and petroleum are sometimes used, however, for treating railway ties. The petroleum serves to dilute and cheapen the creosote and also has some value in retarding the checking of ties in serv-

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assurance that the oil is a pure product, the following tests will aid in arriving at an opinion as to its coal-tar origin:

a. Fraction distilling between 210 and 235° C. is usually solid or contains some solids when cooled to 25° C.

b. All of the fractions up to 315° C. contain tar acids in varying amounts, usually at least 1 per cent calculated on the amount of the fraction tested.

c. The specific gravity of the fraction between 235 and 315° C. is usually not lower than 1.025, and specific gravity of the fraction between 315 and 355° is usually not lower than 1.085 at 38° C., compared with water at 15.5° C. Some pure coal-tar distillates fall slightly below these limits, however.

If the oil does not comply with at least one of the foregoing tests it is undoubtedly not a pure coal-tar creosote.

ice. Petroleum is also used to some extent as an after treatment on zinc-chloride-treated ties, in order to minimize checking.

Water-gas tar and water-gas-tar distillate are sometimes used with creosote or with zinc chloride for treatment of ties. Tars are rarely used alone for preserving wood because of the difficulty of securing a good penetration and because they are less poisonous to wood-destroying fungi than creosote. It has been demonstrated that surface coatings of tar are of no value. Mixtures of coal-tar and coal-tar creosote are used rather extensively in the treatment of ties.

Sodium fluoride is used to a limited extent for preserving wood, but in the United States its use is more experimental than commercial. It is believed from the evidence available to be a fairly good wood preservative; its chief disadvantage is the relatively high price, which is roughly about twice as much as the cost of zinc chloride.

Mercuric chloride is undoubtedly very effective in prolonging the life of wood, but its relatively high price, its extremely poisonous character, and its corrosiveness to metal have militated against it.

PROPRIETARY PRESERVATIVES

There are many preservatives sold under trade names of various kinds. Some of them are coal-tar creosote or coal-tar creosote which has been modified somewhat by taking out part of the solid ingredients. Some of them have had the lighter fractions removed, making them higher boiling than the ordinary run of creosotes. In the main, preservatives thus derived from coal-tar creosote are good and may be used with assurance. Whether it is wise to use them depends upon their demonstrated value and cost as compared with coal-tar creosote or zinc chloride.

There are other proprietary preservatives containing wood-tar products or other oils. The value of these is not so well established, but no doubt some of them have value. In a third group are preservatives made of water-soluble salts, in various mixtures. Whether or not these are good depends upon the materials of which they are composed. Some are very effective and others of little value. Before buying a preservative of this kind the purchaser should insist upon knowing its ingredients and their proportions and whether methods for determining these ingredients are available.

The literature exploiting some of the proprietary preservatives frequently contains extravagant claims as to their properties and effectiveness. Obviously, claims should be proved or discounted. The extent to which a preservative is being used is one indication as to its probable value, but the best measure of the value of a preservative is adequate evidence that it has given satisfactory protection under actual service conditions.

HOW WOOD IS TREATED

To be effective, the preservative must penetrate the wood. Impregnation under pressure is the most satisfactory means of injecting preservatives into wood, and while the various pressure processes differ in details, the general principle is the same in all cases. By the use of pressure the penetration of the preservative is subject to control, so that the amount of the preservative and the penetration may be varied to suit the different requirements and thus result in an economical use of preservatives.

FIG. 49.—Exterior view of a wood-preservation plant. The two testing cylinders or retorts shown are 8 ft. in diameter and 125 ft. long. Overhead are storage tanks for air, and measuring tanks for the preservative. The large storage tanks for the storage of preservative are not shown in the figure.

A pressure wood-preserving plant (see Figs. 49 and 50) consists principally of one or more treating cylinders or retorts 6 to 9 ft. in diameter, about 120 to 150 ft. long, and capable of withstanding a working pressure of 150 to 300 lb. per square inch. Inside the cylinder is a track for the tram cars which carry the wood (see Fig. 51). These cars, loaded with timbers to be treated, are handled in trains and are shoved into the retort by small locomotives. The cylinder door is then closed, and after treatment the cars with the treated timber are removed and the material is loaded for shipment. The treating cylinder is provided with steam coils to heat the preservative, which penetrates the wood more readily when hot.

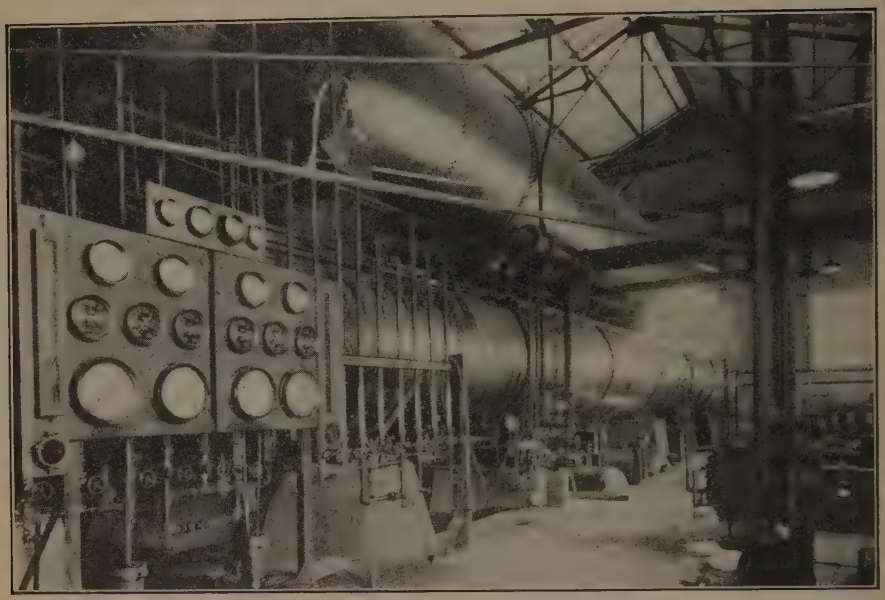

FIG. 50.—Interior view of a wood-preservation plant. Note air, vacuum, and pressure pumps, recording thermometers and gages, which are necessary for the efficient pressure treatment of timber.

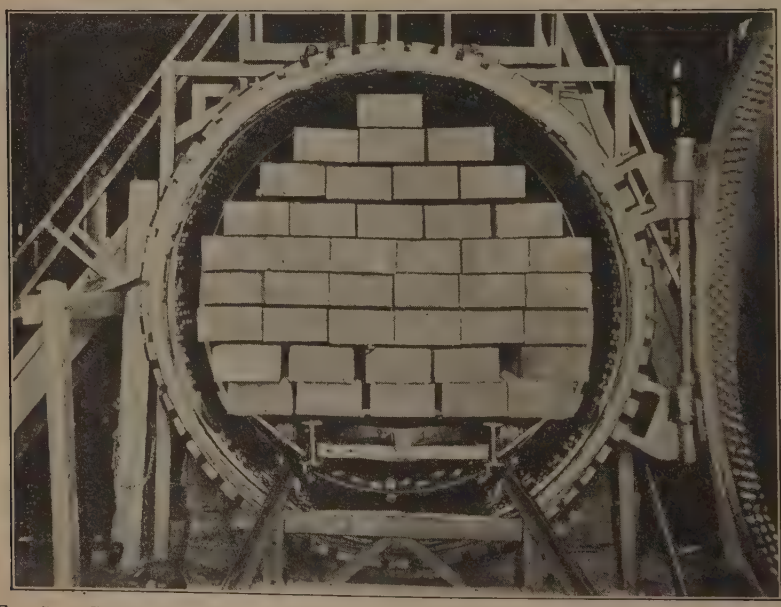

FIG. 51.—Small train loads of timbers are run into the treating cylinders. The door is closed and the preservative, either coal-tar creosote or a solution of zinc-chloride, is forced into the wood under pressure. Note the heating coils between the rails to keep the preservative at the proper temperature during treatment.

In addition to the treating cylinder, there are storage and measuring tanks for the preservative, the necessary pressure and vacuum pumps, and facilities for steaming the timber when necessary.

The pressure processes for the treatment of wood are grouped into two classes: (1) full-cell processes the object of which is to fill the intercellular spaces of the wood with the preservative as completely as possible, and (2) empty-cell processes the object of which is to secure as thorough and deep a penetration as possible, with the use of a minimum quantity of preservative.

DETERMINING PENETRATION OF WOOD PRESERVATIVES

The effectiveness of any good wood preservative is measured very largely by the depth to which the preservative penetrates. This can be determined by the following tests:

The presence of creosote oil is indicated by the dark discoloration, and the degree of penetration may readily be determined by taking a sample at a point free from checks and other imperfections and at a considerable distance from the end. This may be done either with an ordinary ½-in. bit or with an increment borer which brings out a core of wood that shows in cross-section the depth of penetration, and is easily examined. The observation should be made at once, because the oil may spread rapidly over the cut surface. In order to prevent subsequent infection by decay, the hole in the treated piece should be tightly closed with a creosoted plug.

As zinc chloride is colorless, the depth of penetration of this preservative must be ascertained by chemical means. After cutting the stick in two or getting a sample with the increment borer, the freshly cut surface is sprayed with a mixture of equal parts of a 1 per cent potassium-ferricyanide solution, a 1 per cent potassium-iodide solution, and a 5 per cent solution of soluble starch. This colors the treated portion a very dark blue but does not affect the untreated wood. Although the color fades in time, it may be brought back by spraying again. The wood should be reasonably dry when tests for penetration are made. As individual pieces may show an abnormally high or low degree of penetration, a sufficient number of tests should be made to obtain a fair average. Samples should be taken at a considerable distance from the ends of the stick, in order that they may not be affected by the heavy longitudinal penetration from the ends.

STRENGTH OF TREATED WOOD

Preservatives will not make weak timber strong nor restore the strength to timber which has been partially destroyed by decay. Only timber which is naturally suited for its intended purpose and which is in sound condition should, therefore, be treated. The preservative usually does not penetrate throughout the stick, especially the heartwood of

most species, and cutting and framing should be done before treatment. Framing after treatment may expose untreated interior parts of the timber and permit ready access to decay. If some cutting after treatment is unavoidable, the damage may be partly ovecome by thoroughly brushing the cut surfaces with creosote oil. Two coats of hot creosote should be given, if practicable, but one coat would be better than none.

WHEN PRESERVATIVE TREATMENT OF WOOD IS AN ECONOMY

In places where untreated timber would not be satisfactory, because of early destruction by decay or insects, a decided economy would be effected by the use of properly treated wood. This includes railroad ties, posts, poles, mine timbers, wood embedded in damp masonry, sill timbers in various types of buildings, roofing, flooring, and other timbers in heavy mill construction where the relative humidity is high, bridge and wharf timbers, and farm timbers.

The cost of treated wood is necessarily somewhat greater than that of untreated timber; but when one considers the cost of replacement and the greatly increased life of properly preserved wood, this added expense is well worth while for many purposes.

If a timber user knows the average life that treated and untreated timbers are giving, and the cost of each in place, the relative annual costs of maintaining the two can easily be computed with the use of Table 2. A mine operator may have found, for example, that untreated timbers are giving an average life of 2 years and that their cost in place is $6 per set. Assuming an interest rate of 7 per cent, the table shows that timbers which need replacement every 2 years cost annually $0.553 for every dollar of their cost in place. For the $6 set, then, the annual maintenance cost would be 6 times $0.553, or $3.32. Treated timbers may be found to give an average life of 14 years and to cost $7.50 per set in place. The annual charge on timbers with a 14-year life is found in the table to be $0.114 on each dollar of their cost in place. The annual cost of maintaining the $7.50 treated set, therefore, would be 7.5 times $0.114, or $0.86. Preservative treatment in this case, then, would save $2.46 per set annually.

If a timber user knows the cost of treated and untreated timber and the average life of the untreated timber only, an estimate can be made as to how long treated timber would have to last to be as cheap as untreated timber. In the case discussed above, the untreated timber cost $6 in place; the treated, $7.50; and the untreated timber lasted 2 years. The annual charge on the untreated set was found to be $3.32, and since the annual charge on the $7.50 treated set is to equal this, the equation, $7.5 \times y = \$3.32$ may be set up; then the annual charge (on $1 expenditure) equals $3.32 ÷ 7.5, or $0.443. Referring again to the table and looking down the 7 per cent interest-rate column, it is found that an

TABLE 2.—ANNUAL CHARGES ON EACH DOLLAR OF COST OF TIMBERS IN PLACE

Life in years before replacement	Interest rate, per cent						
	4	5	6	7	8	9	10
1	1.040	1.050	1.060	1.070	1.080	1.090	1.100
2	0.530	0.538	0.545	0.553	0.561	0.568	0.576
3	0.360	0.367	0.374	0.381	0.388	0.395	0.402
4	0.275	0.282	0.289	0.295	0.302	0.309	0.315
5	0.225	0.231	0.237	0.244	0.250	0.257	0.264
6	0.191	0.197	0.203	0.210	0.216	0.223	0.230
7	0.167	0.173	0.179	0.186	0.192	0.199	0.205
8	0.148	0.155	0.161	0.168	0.174	0.181	0.187
9	0.134	0.141	0.147	0.154	0.160	0.167	0.174
10	0.123	0.130	0.136	0.142	0.149	0.156	0.163
11	0.114	0.120	0.127	0.133	0.140	0.147	0.154
12	0.106	0.113	0.119	0.126	0.133	0.140	0.147
13	0.100	0.106	0.113	0.120	0.126	0.134	0.141
14	0.095	0.101	0.103	0.114	0.121	0.128	0.136
15	0.090	0.096	0.103	0.110	0.117	0.124	0.131
16	0.086	0.092	0.099	0.106	0.113	0.120	0.128
17	0.082	0.089	0.095	0.102	0.110	0.117	0.125
18	0.079	0.086	0.092	0.099	0.107	0.114	0.122
19	0.076	0.083	0.090	0.097	0.104	0.112	0.120
20	0.074	0.080	0.087	0.094	0.102	0.110	0.118
21	0.071	0.078	0.085	0.092	0.100	0.108	0.116
22	0.069	0.076	0.083	0.090	0.098	0.106	0.114
23	0.067	0.074	0.081	0.089	0.096	0.104	0.113
24	0.066	0.072	0.080	0.087	0.095	0.103	0.111
25	0.064	0.071	0.078	0.086	0.094	0.102	0.110
26	0.063	0.070	0.077	0.085	0.092	0.101	0.109
27	0.061	0.068	0.076	0.083	0.091	0.100	0.108
28	0.060	0.067	0.075	0.082	0.090	0.099	0.107
29	0.059	0.066	0.074	0.081	0.090	0.098	0.107
30	0.058	0.065	0.073	0.081	0.089	0.097	0.106
32	0.056	0.063	0.071	0.079	0.087	0.096	0.105
34	0.054	0.062	0.070	0.078	0.086	0.095	0.104
36	0.053	0.060	0.068	0.077	0.085	0.094	0.103
38	0.052	0.059	0.067	0.076	0.084	0.094	0.103
40	0.050	0.058	0.066	0.075	0.084	0.093	0.102
42	0.050	0.057	0.066	0.074	0.083	0.092	0.102
44	0.049	0.057	0.065	0.074	0.083	0.092	0.102
46	0.048	0.056	0.064	0.073	0.082	0.092	0.101
48	0.047	0.055	0.064	0.073	0.082	0.091	0.101
50	0.047	0.055	0.063	0.072	0.082	0.091	0.101
52	0.046	0.054	0.063	0.072	0.082	0.091	0.101
54	0.045	0.054	0.063	0.072	0.081	0.091	0.101
56	0.045	0.053	0.062	0.072	0.081	0.091	0.100
58	0.045	0.053	0.062	0.071	0.081	0.091	0.100
60	0.044	0.053	0.062	0.071	0.081	0.090	0.100

Based on the formula

$$A = \frac{P(1+r)^n r}{(1+r)^n - 1}$$

in which

A = annual charge
P = amount of initial investment
n = number of years in the recurring period (the average life of the timber)
r = the rate of interest expressed decimally

annual charge of $0.443 on the dollar falls between the 2- and 3-year line and evidently at a point equivalent to a life of 2⅔ years. Thus, it can readily be seen that if treatment adds only ⅔ year to the life of the timbers, it would pay for itself; and the user could be sure from the experience of others that it would add much more than this and would, therefore, be profitable.

If untreated timber is giving long service, treatment might not result in great savings. Very often, however, it might be possible to substitute for such timber a treated lower-grade material that would give as long or longer service, with an annual maintenance charge which would compare favorably with that of the better-grade untreated timber.

There are several advantages arising from the use of treated timber which should not be overlooked, although they may not seem so important as cutting down maintenance costs. As decaying timbers are highly inflammable, preservative treatment, by keeping the wood sound, reduces the fire hazard. Then, a well-preserved timber maintains high strength over a long period of time, while a decaying timber rapidly loses its strength. Preservation by lengthening the life of timber, and by permitting the use of low-grade material, also helps conserve a timber user's resources and the nation's timber supply.

CREOSOTE TREATMENT

Pressure-creosoted timber is successfully and economically used for types of construction where the slight odor or dark color would not be objectionable.

Treatment with coal-tar creosote varies somewhat, depending upon the purpose for which the treated timber is to be used. A standard empty-cell treatment with 8 lb. of creosote per cubic foot is considered excellent for most purposes, especially for timber in buildings. For bridges and structures exposed to the weather, a greater quantity of creosote is usually desirable. Table 3 shows the quantity of creosote per cubic foot recommended by the American Railway Engineering Association for timber for various uses. The recommendations of 16 and 14 lbs. of creosote for several purposes when treated by the full-cell process are considered good practice for railway requirements, although many engineers prefer a 12-lb. treatment by the empty-cell process, especially for highway bridge, and dock work. Either treatment will insure long service.

ZINC CHLORIDE TREATMENT

Zinc-chloride-treated timber is used effectively except when it is placed in water, or in extremely wet locations, such as are necessary in marine piling. In extremely wet locations the increase in life from treatment with zinc chloride is usually less than in the drier locations.

TABLE 3

Class of material	Process and pounds creosote per cubic foot	
	Full cell	Empty cell
Ballast deck bridge plank	16	
Bridge caps	16	
Bridge stringers	16	
Bridge ties	..	10
Bulkhead plank	16	
Building lumber	..	8
Car lumber	..	8
Conduit	..	8
Cross- and switch-ties	..	8
Crossing plank	..	8
Cross-arms	..	6
Dock stringers, caps, and timbers	16	
Drain box and culvert lumber	14	14
Farm gates	..	6
Fence posts and boards	..	6
Guard rails	..	10
Ice-house lumber	14	14
Longitudinal braces	16	
Piling (marine)	22 or refusal	
Piling (land), sapwood less than 2 in	12	
Piling (land), sapwood more than 2 in	16	
Platform plank	..	8
Poles	..	10
Sills for frame buildings	14	14
Sign posts	12	12
Stock pen posts and lumber	12	12
Sway braces	16	
Tie plugs	12	12
Trunking and capping (wires in petroleum asphalt)	12	12
Trunking and capping (wires loose in trunking)	..	8
Water-tank staves	12	

inc chloride is an excellent preservative and has been used for over 70 ears in the United States; is somewhat cheaper than creosote and may e used for the treatment of timber that has to be painted, while creosoted mber cannot be painted satisfactorily.

Standard specifications of the American Wood-Preservers' Association r treatment with zinc chloride provide for a minimum of ½ lb. dry zinc hloride per cubic foot of timber. This minimum is commonly used on ilway ties. On lumber, and any material of small dimensions, 1 lb. of nc chloride per cubic foot is recommended. An absorption of 1 lb. of nc chloride per cubic foot definitely reduces the inflammability of the

wood, as compared with untreated wood, and should give considerably longer service than a treatment of ½ lb. of zinc chloride per cubic foot.

DIFFERENCES BETWEEN MOLDS AND WOOD DESTROYERS

Not all fungi which live upon wood impair its strength; but conditions which promote the growth of molds, blue-stain fungus, and other non-injurious fungi are usually favorable to the growth of the wood destroyers, and these may be active on the same wood that bears the molds. Hence, the presence of mold on timbers intended for any structural purpose should cause them to be looked on with suspicion.

In the early stages of their growth the molds and the wood-destroying fungi sometimes look alike, and there is no simple means by which wood users can separate them at sight. The surface growth of molds is generally cottony or felty in appearance; the mycelium or fine mold threads are interwoven, never compacted into sheets or strands. The mycelium of wood destroyers may be fluffy and glistening but usually are compacted into strands or fan-shaped patches.

The characteristic feature of mold growth on wood is that the minute threads which enter the wood do not bore into the wood fibers or dissolve them. They pass through the spaces between the fibers, or enter them through the natural openings called *pits*, which are found in the walls of certain cells. Starches, sugars, and other contents of wood cells constitute the food of the molds.

The wood-destroying fungi are able to send their threads right through the wood fibers, breaking down the cell walls and utilizing portions of this decomposed material as food. This action very markedly weakens the wood, making it crumbly, stringy, or spongy—in other words, producing rot or decay. The presence of wood-destroying fungi in an advanced stage of growth is evidenced by fruiting bodies, commonly called mushrooms, toadstools, conchs, or brackets.

The principal economic loss caused by molds is through the staining or discoloration of the wood. This is the extent of the damage caused by the wood destroyers in their very early stages; but their work will continue and will finally result in the destruction of the wood, if favorable moisture and temperature conditions prevail.

Utilization of Blue-stained Lumber

Blue stain in sap lumber is not a stage of decay. Although it is the work of fungi, it leaves the strength of the wood practically unimpaired for ordinary purposes. Nevertheless, it is an object of natural suspicion and a source of large degrade losses. Proper kiln drying is the only completely effective method now known of preventing blue stain. In spite of years of experience with chemical dips, no preventative has yet been found which will give complete protection during the warm rainy season. Until a practicable, uniformly effective method of prevention is

ound for cases where kiln drying is not feasible, the proper utilization f blued stock will remain an important way of reducing loss from this ource.

The utilization of blue-stained wood must, however, be undertaken ntelligently. In the first place, kiln-dried material should be chosen in reference to air-dried, for the reason that decay-producing organisms, s well as stain fungi, are likely to be killed in kiln drying. Secondly, efore recommending the use of blued lumber, whether air dried or kiln ried, the holder of such stock should assure himself that it has not ecome infected with decay-producing fungi in addition to the blue stain. he recognition of decay associated with sap stains is difficult, particu-arly when decay is in the early stages or when the staining is heavy.

Since wood destroyers thrive under conditions which favor the bluing f wood, heavily stained material should be examined carefully for signs f decay. Blue-stained rough lumber is freely accepted in lath, scantling, lank, and some of the larger sizes of dimension. More of it could well e used, where sapwood is not objectionable, in the manufacture of rames, sash, doors, trim, finish, millwork, and other products, when the iscolored wood is to be painted or otherwise hidden from view.

Brown Stain

Northern white pine, California white pine and Pondosa pine, and ugar pine are subject to brownish discolorations which are not caused y fungi but rather by chemical reactions within the woods. These rown stains (which occur during both air seasoning and kiln drying in ll three species) apparently do not injure the mechanical properties of he wood. They do, however, injure its appearance and, hence, its arket value.

Preliminary experimental work in the sapwood of western yellow pine dicates that this stain may perhaps be avoided in kiln drying by the use f comparatively low temperatures and humidities. The exact cause and ature of the stain are not yet known.

The complete and satisfactory solution of the problem requires first a hemical study to determine the exact nature of the stain and then the evelopment of commercially practical methods of avoiding stain forma-on. These methods may deal with the handling of the logs, with the asoning of the lumber, or with its treatment by chemical means.

Research workers to date have tried to guess which of these to attack ithout making the underlying chemical study, for which funds have not en available. It is not likely that such a superficial attack will satis-ctorily solve the brown-stain problem. Those who suffer from its fects should see that funds are available for attacking it from the ttom up.

MAKING WOOD FIRE RESISTANT

Fire-retardant paints have been used since the days of the ancient omans and, with various modifications, are still used. Calcimine or

cold-water paints are relatively cheap and convenient to use for certain interior surfaces. For interior use, washable, interior, flat wall paints, made upon a bodied oil or varnish base are satisfactory. These latter products are highly pigmented and dry quickly to dull-appearing films, which are resistant to moisture and washing and which do not mildew. For exterior use there are numerous fire-retardant paints on the market. The most durable ones are made with linseed oil and a high concentration of metallic earth pigments.

The commercial impregnation of wood with fire-resistant chemicals, and employing pressure, dates back to 1895, when Max Bachert erected a plant in New York City and treated considerable timber for use in the construction of warships for the United States Navy. The success of the process caused the city of New York to adopt a requirement in its building code, in 1899, demanding the use of so-called *fireproofed wood* in buildings more than 12 stories high, which requirement is still in force. As a result, fireproofing plants have developed primarily in the metropolitan area. The equipment employed is very similar to that of wood preserving plants, and in addition, dry kilns are required, since wood for interior use must be dried to about 6 per cent moisture content. The cost of such treatment is from $75 to $100 per 1,000 ft. b.m., which somewhat limits its use; though occasionally fireproofed wood is specified by architects for art galleries, trim in theatres, and country estates.

Fireproofing Chemicals

It is estimated that upward of 50,000,000 ft. of lumber was fireproofed in 1927. Methods of fireproofing may be classified as follows:

1. A superficial treatment used as a surface coating, where the fire-retardant compound (as asbestos, various paints, and surface chemical treatment) is used to prevent access of air to the surface of the wood and thus retard combustion. This method is purely superficial and is not so effective as the second method.

2. A treatment wherein the wood is impregnated either partially or thoroughly with various chemical combinations which retard the spread of flame.

When wood burns, it first gives off water vapor. Following this, a decomposition of the wood takes place and volatile gases are driven off, the ignition of which causes flame. As the heating continues, the combustion of the non-volatile wood substance produces carbon-monoxide gas. The combustion of this gas continues the burning until the wood is entirely consumed, and only the metallic salts originally present in the wood and the carbonates formed during the burning are left.

Chemicals used in fireproofing to control these gases react in various ways when subjected to heat, which reaction is utilized in all fireproofing processes.

Salts like alum and carbonates of soda having large amounts of combined water may be used; the disadvantage of such agents is that, being soluble, they are readily leached out and therefore are not so well adapted to the fireproofing of wood intended for exterior use.

The ammonium compounds are invariably effective, and so are the readily reduced oxides of tin, lead, zinc, antimony, and bismuth; the chlorides, either organic or inorganic, in particular, halowax (naphthalene tetrachloride), the carbonates, such as manganese carbonate, that liberate carbon dioxide at a comparatively low temperature, and the ferrocyanides, and sulphocyanides, which evolve nitrogenous vapors when exposed to heat.

There are other fusible materials, such as borax and ammonium phosphates, that are also effective; when the wood is ignited, they flow around the glowing carbon and thus prevent combustion. Another method is to load the fiber with so much mineral matter that it will not burn.

Other chemicals, such as sodium carbonate, sodium bicarbonate, and oxalic acid, have a somewhat retardant action on the combustion but not sufficient for practical purposes. Commercial treating plants use ammonium phosphate, sulphate, sodium borate, and ammonium chloride, because of their cheapness, effectiveness, and practicability of treatment. A number of the fireproofing paints can be used to advantage and are giving satisfaction on railroad buildings, theatres, and other large edifices. Sodium silicate is used generally as a base for these paints, and various pigments are added to give color.

"Fireproofing" of wood with some fire-retardant chemicals reacts on the properties of the wood and in many instances produces results which are not favorable. In order for a fire-retardant process to be practical it should be permanent, the chemicals used should be cheap and abundant, should be non-corrosive and non-hygroscopic; they should not have a marked effect on the strength of the treated wood, or stain or discolor it; neither should they affect the workability of the wood nor be of a decidedly poisonous nature.

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CHAPTER VI

THE USE OF PAINTS AND STAINS

This chapter contains information regarding the proper use of paints and stains and points out how to avoid certain difficulties which sometimes are encountered.

The various kinds of lumber suitable for structural purposes will last indefinitely, when subjected to ordinary weathering, provided they are kept well painted. Striking illustrations of the truth of this statement are afforded by the wonderful condition of many centuries-old dwellings which have been properly maintained. Such structures may be found in every one of the original colonies, but they are most common throughout New England, to whose shores in the sixteenth century came many of the most skilled woodworkers, decorators, and other artisans from the mother country. Since many kinds of lumber are represented in these structures, the durability of painted wood in general is well shown.

The greatest durability is obtained when dwellings are coated with at least three coats of paint and preferably with four coats. Three coats of high-quality paint, however, should give satisfactory service for several years before repainting is required. At the repainting period, preferably two coats should be applied.

Definition of Paint.—Paint is a mixture of solids and liquids, the solids being pigments (natural or manufactured) and the liquids being oils, thinners, and driers (solutions of metallic salts). The most commonly used white pigments are white lead and zinc oxide. In recent years, titanium pigments and lithopone have come into wide use. Colored pigments may be natural earth pigments, such as iron oxides, or chemically prepared colors, such as chrome yellow and ultramarine blue. Metallic powders, such as aluminum powder and zinc dust, are also used as pigments in certain types of paints. The liquids used are linseed and other vegetable oils, turpentine or thinners made from petroleum, and driers. The functions of the pigments are to give color, opacity, and thickness to the film and to protect it from too rapid disintegration. The function of the oils is to bind the pigment particles together, give adhesion to the painted structure, and gloss to the film. The thinners are used to vary the consistency of the paint in order to suit the conditions of application and also to give penetrating qualities to the film, enabling it to make a good bond with the structure. The driers hasten the setting and final drying of the paint.

Kinds of Paint.—The paint used may come in two forms: (1) as a paste to be reduced on the job by the painter to a condition suitable for application, or (2) in prepared form, ready for use, with the possible addition of slight amounts of turpentine for the first coat. In the case of a paste paint, it is customary to add to 100 lb. of the paste from 4 to 6 gal. of linseed oil and a pint of liquid drier. The mixture may be thoroughly stirred in a barrel or tub. Loss by spattering should be avoided. A gallon or more of turpentine may be used to take the place of part of the oil for first-coat work. If a colored paint is desired, color ground in oil may be added to produce the desired result. The paint should then be stirred for a long period in an endeavor to get the color thoroughly into the mass in order to prevent streaking.

Application of Paint.—In the case of a prepared paint, full directions for use which usually appear upon all packages should be carefully followed. In case such directions are lacking, however, the following general rules will be found useful: Before the paint is applied, the wood should be dry and free from surface moisture. Painting should never be done in damp weather except under cover. If the wood has not been painted before, any visible sap streaks or knots should be brushed preferably with turpentine just before applying the paint. Shellac is often used. The turpentine treatment will soften the resin in the wood and allow the priming or first coat of paint to soak thoroughly into and combine with the resin, thus preventing scaling. For the priming coat, from 1 to 3 pints of turpentine should be added to a gallon of prepared paint. The mixture should be thoroughly stirred until it is uniform throughout (see Figs. 52 and 53). Since paint will not stay mixed indefinitely, it should be thoroughly mixed every time it is used. Incomplete stirring makes the paint uneven in body. A large majority of paint troubles can be traced to incorrect stirring.

Application of Paint by Hand Brush.—The paint may then be applied by brushing out to a thin coat on the new wood. The turpentine will serve to carry the paint into the pores of the wood and thus provide a good bond. When the priming coat has become thoroughly hard and dry, which, as a rule, will take at least 3 days, although a week is better, all the nail holes and other imperfections may be filled with putty. The second coat of paint may then be applied, using the paint without the additional thinner, except that a small quantity of turpentine may be added if the paint is heavy. One pint of turpentine to a gallon of paint is generally sufficient for this purpose. The turpentine will cause the second coat to dry with a semigloss surface. After a suitable drying period, not less than 48 hours, the third coat may be applied. No turpentine or other thinner should be added to the paint for the third coat, if it is desired to obtain a film, rich in oil, that will dry to a high gloss surface. When desired, an additional coat may be applied. The

application of a number of thin coats of paint gives a more durable job than can be obtained from two thick coats.

When old surfaces are to be repainted, all loose, scaled paint should be removed, and rough, checked surfaces lightly sanded with fine sand-

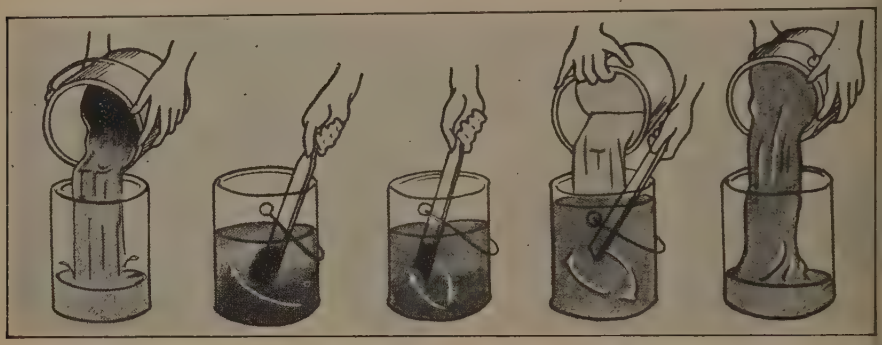


FIG. 52.—How to mix paint and enamel: (1) pour off one-fourth of contents into another clean can; (2) loosen any settled pigment with a paddle. Paddle should be 1¼ in. wide for 1-gal. cans and 3 in. wide for 5-gal. cans; (3) mix thoroughly, using a lifting and beating motion; (4) gradually add liquid poured off, stirring as in (3); (5) box paint several times by pouring back and forth from one can into the other.

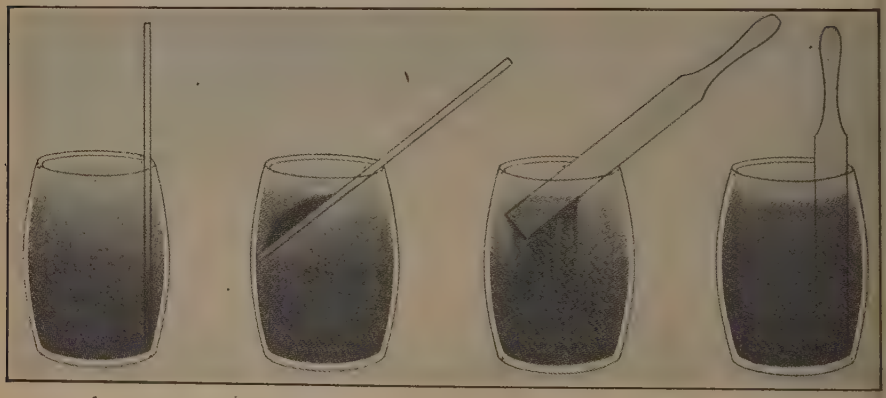


FIG. 53.—Mixing paint in barrels and half barrels: (1) push paddle to bottom of barrel keeping flat side against side of barrel; (2) pull handle toward you, lifting pigment nearly to the surface; (3) twist paddle to the right, throwing pigment off the paddle; (4) bring paddle back edgewise to position No. 1.

NOTE: To avoid too great a strain on mixing paddles, loosen paint by rolling barrel for about 10 minutes. Stir until paint is of uniform consistency throughout, then occasionally when any paint is removed from barrel.

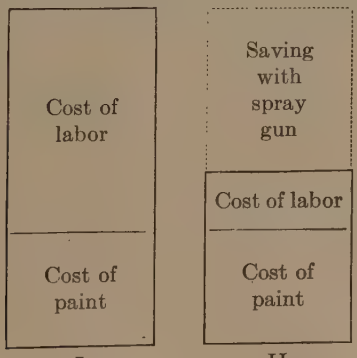
paper. The work may then proceed as for the second and third coats on new wood.

Application of Paint by Spray Machine.—While practically all house-painting jobs at the present time are done by hand brush, the spray-paint-

ing machine has been recently developed for this purpose. On broad, expansive surfaces the spray-painting machine usually will do, with one operator, three times as much work as the hand brush, and sometimes the proportion is even greater. For painting a number of farm buildings, for instance, the spray-painting machine is exceptionally well adapted. Its extensive development in this field will doubtless greatly lower the cost of painting wooden surfaces.

Since the spray-painting machine usually applies a thicker coat of paint than the hand brush, its proper operation and service require skill and knowledge, just as does the proper use of the brush. The machine should be adopted as a supplementary service, and the more intelligent journeymen should be thoroughly instructed in its use and care. The following comparative figures may be of interest:

	Square feet painted per work day of 8 hours (per man)	
	By spray gun	By brush
Wood exterior	3,000	1,000
Metal	6,000	1,200
Brick	3,500	800
Stucco	2,600	700
Concrete	3,500	1,000
Shingles	3,500	1,000
Mill interior	4,500	1,800
Radiators (radiator feet)	500	100



Graphic Comparison of Costs

I. Brush.
II. Spray.

SCHEDULE OF PAINTS FOR VARIOUS PURPOSES

Requirements for exterior and interior painting of various kinds, for varnishing and staining woodwork, and for many other applications call

for the use of a variety of paints and finishes. A list of some of these is shown in the following schedule:

PAINTS FOR VARIOUS PURPOSES

Paints for exterior surfaces	Wood	Weatherboarded dwellings, churches and factories, fences and wooden structures.	Paste paint to be reduced on the job or prepared paint, + preferably tinted. Paint to be made of white lead or a mixed pigment base of white lead and zinc oxide, or white lead, zinc oxide, and titanium pigment, with or without a moderate percentage of inert pigments. Class A
		Shingled roofing and siding.	Same as Class A or a creosote shingle stain
		Sheds, barns, and outbuildings.	Same as Class A or prepared iron-oxide paint or graphite paint
		Porch floors.....	Colored-floor paint containing durable varnish
		Window shutters.....	Same as Class A or chrome-green shutter paint for finish coat only
	Metals	General structural iron and steel girders, roofing, siding, etc.	Rust-inhibitive paint, red lead, iron oxide, graphite, etc. Class B
		Galvanized iron.....	Prime with 5 per cent water solution of copper salt. Dry and apply class B paint
		Tinned roofing and flashing.	Clean all grease with gasoline. Apply Class B paint
	Brick, concrete, stucco	Brick walls.....	Same as Class A or prepared brick and cement paint with china wood-oil liquid
		Cement and concrete structures and stucco surfaces.	Prime with 25 per cent water solution of zinc sulphate if cement or stucco is new (to neutralize alkali). Dry and apply Class A paint or prepared cement paint with china wood-oil liquid
Paints for interior surfaces	Metal Wood	General trim, stairways, doors, paneling.	Class A Paints finished with or without enamel or varnish finish
		Doors, paneling, floors, etc. (transparent finish).	Fillers, stains and varnish as desired
		Metal work.....	Same as for exterior metal work

PAINTING DEFECTS

Painting defects seldom show on wooden structures which are well painted. If they do, they are generally due to conditions existing at the time the paint is applied. The methods of preventing the development of such defects are outlined in the following paragraphs:

Chalking.—The natural process of weathering for a satisfactory paint is chalking rather than cracking. Chalking should, therefore, be looked

for in a paint. If a paint chalks mildly within the period of a year or two, it should be considered a desirable characteristic, provided the chalking is not of such a nature as to "wash" off after 3 or 4 years and leave an unprotected surface. Paint of the proper composition will chalk mildly and often maintain a good surface (*free from cracking*) and a good moisture and weather-resistant film, for a period of 5 years.

Blistering and Peeling.—Blistering of paint is generally due to the presence of moisture within or upon the painted surface to which the paint is applied. While upon badly water-soaked wood it is possible to produce a blister which may include even the priming coat of paint (all three coats being forced off), it is usual to find that the blister is formed of the two outer coats of paint, the priming coating being still attached to the wood. This is probably due to the fact that the priming coat is well anchored to the wood in a thin film which allows the moisture to emerge from the wood without becoming distended, whereas the two finishing coats form a film through which the moisture cannot pass in quantity without distending the film. When well-primed wood is wet by rain, the application of finishing coats over the wet primed surface may also result in blistering. Obviously, the cause of blistering is moisture which should be avoided at painting periods. The insufficient drying of plaster on a new structure and the painting of rain-soaked siding are two usual causes of blistering.

When cheap ochre priming is used on wooden surfaces, or when white paint is applied directly to highly resinous wood, peeling may develop. Ochre priming, however, has been largely discontinued by American painters. Wherever resinous wood is used, the priming coat of paint should preferably be of the red lead-zinc dust-aluminum powder type of the following formula before the final coats of white or light-tinted paints are applied.

TRIMETAL PRIMER

Red lead	12 lb.
Zinc dust	2 lb.
Aluminum powder	1 lb.
Linseed oil	2 qt.
Boiled linseed oil	1 pt.
Turpentine	1 pt.
Turpentine liquid drier	½ gill

The use of this special primer upon such wood, and the allowance of a weathering period for the primer to get thoroughly dry and hard previous to the application of the finishing coats, is desirable and, as a rule, will show entirely satisfactory results.

Typical blistering and peeling of paint on house siding result when the wood surface in contact with the paint coating becomes wet. It is said to be especially likely to occur if the painted surface over wet

wood is heated, perhaps by strong sunlight; the theory being that part of the moisture is vaporized and that the resulting gas pressure forms the blister.

If examined shortly after their first appearance, typical moisture blisters are found to be turgid pockets between coating and wood filled with water. On puncturing them with a penknife the water flows out. The coating can then be taken by the loosened edge and peeled off, leaving the bare wood exposed. Very often the water-saturated paint film is tough and elastic and its adherence to the wood so weak that the tear does not stop at the edge of the blister but continues so that the coating can be peeled off in fairly large shreds. More rarely the moisture pocket may be observed between paint coats instead of between paint film and wood surface, in which case the theory underlying the phenomenon is more obscure.

If the blisters are not punctured while they are full of water and good drying conditions prevail for some time, the moisture passes out and the loosened portions of the coating remain intact but are flabby. The dry paint film is by no means so tough and elastic as it was when wet and is likely to chip off in small flakes when punctured with the penknife, instead of peeling off in large shreds. That is especially true as time passes and oxidation of the vehicle proceeds, making the paint increasingly brittle. Left undisturbed, the brittleness finally reaches a point where the loose portions of the film crack and flake off of their own accord.

Under certain circumstances the presence of free water in the wood may seriously weaken the adhesion of the paint coating to the wood surface, without being present in sufficient quantity to produce visible blisters.

Weathering of Primers.—If a new house is to be painted and it is felt that there may be danger from the moisture in the wood it is safer to apply a priming coat of paint and allow it to weather for a month or two before applying the finishing coats. The priming coat of paint penetrates the wood, becomes well anchored to the pores, and generally forms a film of such a degree of permeability that the moisture in the wood or within the plaster may be drawn out without disturbing the priming coat. This priming coat, however, shows sufficient moisture resistance from the exterior surface to prevent any substantial amount of moisture from coming in and causing warping and shrinking of the wood. It is absolutely necessary that all wood be primed either soon after it is put in place, or, preferably, before. After priming and while waiting for the wood to dry, finishing coats may be applied in good weather with satisfactory results. It should be remembered, however, that when this system is followed, the application of the finishing coats should be made *within a reasonable* period of time, depending on weather conditions. If the job is delayed until the priming coat becomes chalky and badly

weathered, one additional coat will produce a faded flat surface. On the other hand, if the priming coat weathers only until a hard, flintlike surface is formed, the finishing coats of any type of paint may not secure proper penetration, and peeling in sheets from certain areas might occur. When such conditions are found on the priming coat and it is desired to repaint at once, the priming coat should be well sanded or otherwise prepared to receive the finishing coats.

Non-drying and Washing.—Certain pigments and colors give slow-drying mixtures when ground with linseed oil. It is sometimes possible to add boiled linseed oil and rapid drying varnishes as part of the composition to overcome such characteristics. For instance, in the production of window-shutter greens, which contain normally slow-drying pigments, it has become customary to use special quick-drying liquids. The addition to a paint of too much raw linseed oil and not sufficient turpentine and drier is another cause of slow drying.

Temperature and light are necessary for the drying of paints, and if painting jobs are done during the time of year when there is a minimum of light and fairly low temperatures, very much slower drying will be observed than under normal conditions. These matters should be taken into consideration by the painter doing the work, and sufficient thinner and drier should be added in the undercoats to give hard-drying, firm foundations. High pigmentation of the finishing coat will often overcome softening troubles which might occur with paints of lower pigmentation. Paints which are applied during the late fall months, when there is apt to be considerable dampness in the air, and when the temperature is low, or in the winter time, are apt to show slow-drying characteristics and subsequent "washing." During such periods of slow drying, the "tacky" film absorbs moisture from the air, which becomes emulsified with the oil contained in the paint, and firmness is never obtained. Several months later, during rainy periods, the paint may become further emulsified, and "washing" may be observed. Good weather is a prerequisite for exterior painting. Acid gases in manufacturing centers are also the cause of washing in industrial communities.

Alligatoring.—The alligatoring of exterior paints is often due to the application of finishing coats over soft (semidried) priming or underlying coats. If the latter are too rich in oil, or if insufficient time has been allowed for drying, and if hard-drying finishing coats are applied, differences in contraction and expansion of the coats may cause alligatoring of the outer coat. Obviously, the remedy is to allow the priming and other undercoats to dry to thorough firmness before applying the finishing coats. Priming coats reduced with volatile thinners dry hard.

Darkening.—Darkening of paints is more often due to soot deposition than to any other cause. In industrial communities this is noticed more often than in the suburbs where the air is clean. Paints which do not

dry hard and which get "tacky" in damp weather are most receptive to the retention of soot deposited from the air. Paints which contain a high pigment concentration or pigments which give rapid drying to the film seldom show any marked retention of soot, the surface being of such a nature as to allow the soot deposits to be removed by the rain.

Gas Discolorations.—White and light-tinted paints containing lead compounds are also darkened by the hydrogen sulphide generated in some industrial communities, which acts upon the lead content to produce a gray or black deposit sometimes having a metallic luster resembling graphite. Where such discoloration is noted, it is generally observed upon freshly applied soft films, which are quite permeable to gas. After paint has aged for a few months and become hard and dry, hydrogen-sulphide gas *has much less darkening action.* Even where it has darkened paint, later exposure at a time of the year when there is less gas in the air may effect oxidation of the black deposit to the normal color. Where it is necessary to remove the discoloration at once, hydrogen peroxide or a dilute solution of acetic or muriatic acid sponged on the surface will remove the deposit. The surface should then be sponged with water to remove the chemicals.

Copper Stains.—It is not uncommon to see white paint which is stained to a yellowish color below openings screened with copper or under eaves where copper leaders and gutters are used. While some paints stain much less than others, all paints may show this type of discoloration unless the copper is protected. It is true that copper screening and roofing in certain parts of the country do not throw off effective amounts of staining material, but the reverse is true in damp, humid climates, and a slight surface corrosion of the metal is sufficient to stain white paint. Obviously, the painter should ask that the owner allow him to put a coat of oil or clear varnish on the copper screening and roofing, which will serve as a protective for a substantial period of time. Pigmented oils and varnishes are much more durable, and if the owner does not desire the original color of the copper to show, it is more satisfactory to coat the metal with paint or pigmented varnishes. These can be made to harmonize with the color scheme used upon the siding and trim.

Brown Staining.—The discoloration or staining shown on redwood and red cedar is generally due to the presence of large percentages of coloring matter in them. In fact, leaching of these woods over long periods of time may produce practically white cellulose, thus indicating the high percentage of staining matter present. This staining matter, however, may not be resinous, and its effect upon paint should not be confounded with the type of staining caused by resins. The staining matter present in damp wood is rapidly drawn out to the surface by the sun during moist periods and runs down the siding to dry in blotches. Such discoloration on existing surfaces may often be removed by sponging

the surface with a 50 per cent water solution of alcohol. When it has become so oxidized that this reagent is not effective, a repainting coat may be necessary.

Mildew.—Another type of darkening of surface is due to the formation of mildew. This is most often noticed in southern communities where both the temperature and the moisture content of the air are high, and where favorable conditions obtain for the development of fungi. It is commonly observed on slow-drying dark colors. Upon paints which remain soft in such climates, a "tacky" surface is shown, and when dried plant pollen and vegetable matter is blown against the paint, it acts like fly paper and retains the pollen. Mycelium and spores then develop and usually produce a dark-green or black discoloration (*Aspergillus niger* or *Pencillium glaucum*). The defect, however, is not common. Mercurial salts have been proposed as constituents of paint to prevent such growths, but the high pigmentation of the finishing coat of paint with the proper types of hard-drying pigments is much more effective. With dark paints, where the use of varnishes is possible, such as on shutter greens and Indian reds, quick and hard drying may be obtained which prevents the attachment of the dried pollen. It should be pointed out, however, that where fungi exist in the wood that is to be painted, it is possible for these fungi to penetrate through subsequently applied coats of paints. In these instances the use of about 2 per cent of either mercury or cuprous oxide in a hard-drying coat of priming paint has often overcome the difficulty. The presence of a substantial percentage of zinc oxide in the finishing coat of paint is another assurance against mildew.

Spotted Storm Effects.—Continuous rain lasting several days, especially when accompanied by electrical storms, may absorb nitrates and peroxides from the electrical discharge. When such rain strikes a freshly painted surface, the rain may penetrate and change the refractive index of the coating in such a way as to cause unsightly spotted effects. Apparently, such gas-saturated rain permeates a film more rapidly than ordinary water. Rubbing the spotted surface with alcohol will extract much of this moisture and restore the paint film to its original condition. Where this is not possible, merely allowing the paint to weather for the period of a month or two will often restore its original color.

Segregated Spotting of Paints.—Light gray paints often show a curious type of spotting. While the body of the job may be of the desired tint, dark-colored spots may show throughout the surface. These are sometimes due to aggregates of the black tinting color used. These aggregates, if not properly dispersed throughout the paint, may make certain portions of the film darker than other portions. The effect is usually not obvious until the paint has weathered for a year or more. This is not the only cause of such spotting. Proper dispersion of the tinting color

is important. Less trouble of this sort is experienced in light grays that are applied over the red lead-zinc dust-aluminum powder primer than directly upon wood through which moisture, resinous matter, or coloring matter may come. The latter is a frequent cause of segregated spotting.

FINISHES FOR INTERIOR WOOD SURFACES

Floor Finishes.—On new hardwood floors, a transparent finish which colors the fibers of the wood, brings out the grain, and provides a durable protective surface is desirable.

While a good quality of floor varnish supplies a protective surface, the mere application of varnish to bare wood cannot be considered as a decorative finish. The color resulting from the application of clear varnish to bare wood is too light for a practical and harmoniously blended floor.

Classification of Finishes.—It is necessary at this point to set forth clearly the three general methods of treating a floor in color.

1. The wood may be stained which means introducing a dye or colored pigment into the wood fiber, causing the surface of the wood itself to take on the desired color; it is then protected by transparent finishing and protective coats.

2. Another type of color finish is known as *varnish stain,* which means a combination of stain and varnish or a colored varnish.

3. Then there is the painted floor, in which the color is introduced in the form of opaque pigments, which gives a solid uniform color and completely hides the grain of the wood.

Finishes 2 and 3 are not recommended for new hardwood floors.

The staining treatment makes possible the most beautiful type of color effects. Not only is the desired color introduced, but also the characteristic beauty and texture of the wood itself are brought out. The essential thing about the staining treatment is that the actual fibers of the wood are colored, but not hidden in any way, so that the figure or texture of the wood is seen through the transparent finishing coats. The paint treatment is a surface treatment. That is, the color is confined to a film resting upon the surface of the wood, and there is slight penetration into the wood itself.

This distinction is important. The staining treatment brings out the beauty of the wood and represents the most effective treatment from the standpoint of fixing the color in the wood itself; for the stain penetrates a considerable distance into the fiber of the wood. This penetration varies for different kinds of wood and different kinds of stain; but the general rule holds true that the stain does carry the color down below the surface. If, then, the stain is properly protected with finishing coats, it gives a color finish which is permanent.

In considering the matter of the durability of any floor-stain treatment, two fundamental factors are involved: (1) the degree of penetration, and (2) the permanence or impermanence of the color used. A brief consideration of the various kinds of stains which are desirable for use follows:

Types of Stains.—Stains are ordinarily divided into the following three classes: penetrating oil stains, spirit stains, and acid stains.

Penetrating oil stains consist of oil-soluble analine dyes, dissolved in liquids which are solvents for oils and which mix with oils. These stains may or may not actually contain oil. Most of the mahogany and walnut stains sold over the counter in small packages are of this type.

The greatest advantage in using a penetrating oil stain is that it does not raise the grain of the wood and is, therefore, recommended for softwood. On the other hand, these stains have the great disadvantage of losing their color when exposed to the sunlight. This is particularly true of such colors as light mahogany, blues, greens, etc. In certain brown shades such as the popular walnut, this type of stain gives satisfactory permanent color.

The fact should be emphasized that when penetrating oil stains are used for finishing, a coat of shellac must be applied over the stain before varnish is used. Otherwise, the varnish may not dry hard, and the stain may bleed through.

Spirit stains can not always be used, as they may be fugitive to light and have no advantage over the penetrating oil stains. They are alcoholic solutions of dyes and are not always permanent; that is, they do not hold up well in a solution, and some cannot be kept in tin cans, due to the action upon the tin of certain acids in the dye.

Acid stains—sometimes called *water stains*—give the most permanent wood finish. This type of stain represents the solution of acid dyes in water. In some cases, certain chemicals also are present, but the general name of *acid stain* is applied to the group. These stains may be reduced or thinned with water and are frequently called *water stains*. Either name is correct, but the term *acid stain* is ordinarily used in the trade.

Because of their permanence in sunlight and the clarity, depth, and richness of color they impart to the wood, acid stains would be used universally except for the fact that this type of stain has one disadvantage: It raises the grain of the wood, which often makes the stain unsatisfactory for use on softwood.

Application of Stain.—The surface to be stained should be properly sanded, cleaned, and dusted. Painters often sponge the wood before sanding, which gives a greater penetration and more even dyeing of the wood fiber. Stir the stain well before applying. Use a soft-hair brush about 2½ to 3 in. in width for the work.

Apply the stain freely and cover all parts of the surface evenly; apply it parallel with the boards. Go over the surface again immediately, with the same brush, without putting on any more stain. This makes a deeper and more uniform color and the brush picks up spots where the stain is heavier. If stain is not used freely, a blotchy, uneven effect will result. Let stand from 6 to 12 hours, depending on drying conditions. Sand lightly. Thin if needed with distilled water.

Application of Color Sealer and Developer.—The surface should be sealed over the stain coat either with shellac or with a thin coat of a special clear lacquer. This serves as a binder and prevents the varnish from bleeding through the final protective coating. When the special lacquer is used, the beauty of the color and the satiny effect of the finish are greatly enhanced.

This special lacquer is quick drying and is designed especially to develop a soft, clothlike appearance in the stain. Color developer will dry thoroughly in about 2 or 3 hours, after which it should be lightly sanded.

Application of Wood Filler.—All open-grained woods need the application of a paste wood filler to fill the pores of the wood. The filler is colored either a blending or a contrasting tone and applied at this stage of the finishing routine.

The Protective Surface.—The wearing qualities of the finish are entirely dependent upon the final protective surface.

A good-quality floor varnish provides an excellent protective surface. It has gloss and water resistance and is elastic, clings tightly to the wood, and is tough and durable.

The disadvantages in the use of varnish are its tendency to "yellow" with age and its slowness in drying.

A protective finish combining the properties of varnish and lacquer is advocated. This varnish-lacquer finish is tough and durable, water resisting, practical of application through brushing, and quick drying.

Shellac is not recommended as a durable protective surface. It is brittle and quickly affected by water.

Two coats of varnish or varnish lacquer are necessary unless a final protective coating of wax is used, in which case one coat is sufficient. The first coat should be lightly sanded.

Application of Wax.—A final protective coating of wax is advantageous from the point of view of durability, economy of upkeep, and appearance.

A coat of wax over varnish, or varnish lacquer well rubbed into the surface, acts as an excellent preservative. It is easily removed, and the finish on a floor kept well waxed will last for a great many years without refinishing, even when subjected to hard wear.

A waxing apparatus, either hand or electrically driven, is an investment which will add many years to the life of a well-finished floor.

COLOR HARMONY IN INTERIOR FINISH

The floor is the plane which holds the four walls of a room together and provides a substantial foundation for furniture.

In furnishing a room, it is well to follow the same decorative principles that Nature uses. The ground is always the darkest area, and the sky the lightest. Trees and shrubbery are in middle values between earth and sky.

The floor should always be darker than the walls in order to give the appearance of a substantial foundation for walls and furniture.

As the natural color of the majority of woods is light, the deep, rich tones desirable in floors are obtained through staining the wood before the protective coat of varnish is applied.

The so-called *natural* wood stains such as oak and walnut, which have been associated with wood floors for many years, are no more "natural" than grays, greens, and blues. They have become the generally accepted colors for wood floors only through usage.

Blending Wall and Trim.—In small or medium-sized rooms with numerous doors, windows, and openings, woodwork in a strong contrasting shade to the walls cuts up the wall space and makes a room appear smaller.

If a color is selected for the woodwork which blends with the wall color, or is the same as the wall color, the room will appear more spacious.

In large rooms with broad expanses of wall space, a contrasting color in trim and doors will serve to break the monotony of the wall spaces. The finish of the woodwork and the finish of the furniture should bear a harmonious relation.

Planning the Color Scheme.—Harmony in color of walls, woodwork, floors, drapery, and upholstery is essential to a tasteful and pleasing interior. Every room in a home should be planned with a definite color scheme in mind. Successful color schemes are never attained by adding colors in a haphazard fashion.

A permanently pleasing color scheme is composed of both harmoniously blending and harmoniously contrasting colors. The harmonious relation of the colors selected for walls, trim, and floor is the basis of a successful color scheme.

The following chart may be of some help in selecting harmonious combinations. Much, however, depends on the shade or tint used and the area of the surfaces.

HARMONIOUS COLOR COMBINATIONS

Walls	Trim finish	Floor finish
Cream	Old maple	Deeper tone of trim color or blue green
Buff	Blue	Medium walnut
Pale yellow	Green	Dark oak
Light amber	Green blue	Russet
	Medium walnut	Green
Light gray	Medium gray	Gray blue
	Gray blue	Blending deeper blue
	Gray green	Blending deeper green
	Lavender-gray	Old maple
Light gray blue	Blending gray	Old maple
	Light walnut	Deep gray blue
	Old maple	Medium gray
	Blending gray blue	Medium walnut
Light gray green	Blending gray	Medium walnut
	Old maple	Medium gray
	Blending gray green	Dark oak
Light green	Lavender gray	Old maple
	Medium gray	Dark gray
	Gray green	Medium walnut
Light green blue	Green blue	Old maple
	Light walnut	Medium walnut
	Violet blue	Medium gray
	Old maple	Russet

SELECTION OF COLOR FOR EXTERIOR PAINTING

The appearance of a house may be greatly improved or greatly marred by the selection and distribution of colors in painting. It is usually more satisfactory to use the same color for both body and trim of small buildings.

The selection of a painting scheme should be guided by considerations of design and setting—for example, whether the house is located in a prominent open spot or is partially hidden by trees and shrubbery. The architectural design of the building, however, frequently imposes limitations upon the selection of the colors and combination of colors that can appropriately be used regardless of the setting.

Neighboring Houses.—If the house is closely flanked by neighboring houses, the selection of a color scheme may be influenced by the colors in the neighboring houses. If the painting scheme of a house does not blend with its neighbors', it will appear "out of key" no matter how good the individual scheme may be.

Neighborhood painting schemes are effective when possible. A row of houses will be improved in appearance if the individual painting schemes are selected with a view toward harmony with one another.

Influence of Surfaces.—The idea of color cannot be dissociated readily from the surface to which it is to be applied; for to the extent that a color is warm and expanding or cold and contracting in effect, just so is the surface affected to which the color is applied.

Light, warm colors, tints and shades of yellow, make surfaces appear larger. Dark colors tend to make the surface appear smaller.

Light grays or greens do not seem to change a surface to any extent. Bright, warm colors containing red or orange make a surface seem nearer to the eye than the medium neutral or cold colors such as dark gray or dark green and especially blue green.

The Small House.—As a rule, light, warm tints like ivory and cream, are suitable for the small house, as such colors will make any building appear larger. Certain light grays and gray greens may sometimes be used for a building which is not surrounded with trees. These colors, too, will harmonize with practically any color on the neighboring house.

The Large Building.—Darker colors make a large house appear more hospitable. Brown and russet combinations are effective, and also browns and greens, and grays and blues, provided they are suitable or proper for the particular architectural design.

The Tall, Narrow House.—A tall, narrow house can be made to appear lower and broader by emphasizing the horizontal lines and, where the design permits, by making the lower story a darker color than the stories above. A too strong contrast is not usually desirable. A dark roof also tends to reduce the apparent height.

Proper Coloring Adds Value.—There is no more reason for using an ugly color on the exterior of a house than there is for using it in wearing apparel or interior surroundings.

There are as many pleasing colors obtainable in house paints today as there are drab and ugly ones.

A house built to live in or as a speculation will have greater value if it is attractively painted.

Drab grays or muddy or greenish browns should be avoided. Trim colors may be very gay and distinctive provided the surroundings and architecture allow for conspicuous trimming. Bright blues are effective, and blue greens and yellow greens. Golden yellow or orange adds a gay note.

Homes of wood construction allow for highly effective color treatment, even though, as a general rule, the use of strong or contrasting colors should be limited to such accessories as flower boxes and shutters.

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CHAPTER VII

METHODS OF PREVENTING TERMITE DAMAGE

One of the forms of life most destructive to wood is the group of wood-boring insects known as *termites*, or "white ants." Often their damage to wood is mistaken for that caused by rot or decay, which is quite different and is due to lower forms of plant life, which also destroy wood.

TERMITES

Termites are not true ants, although superficially they are antlike and live a social life in colonies made up of different forms or castes. In

(*Courtesy Bureau of Entomology.*)

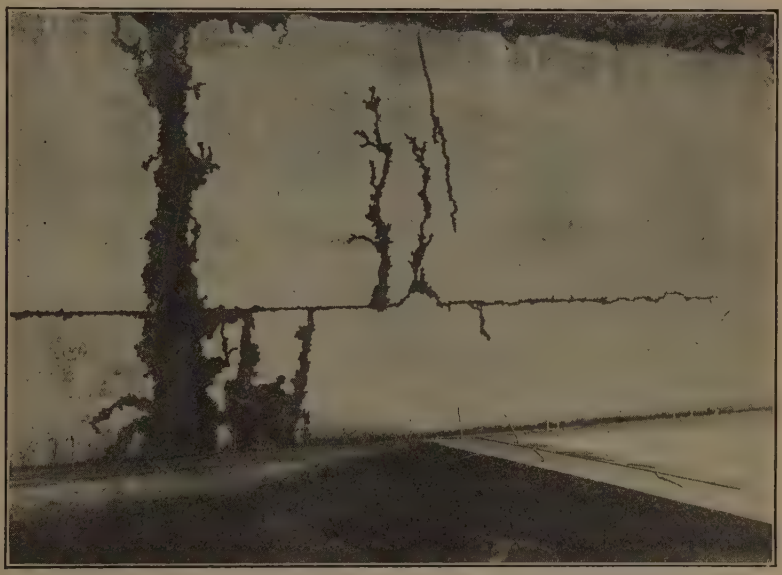
FIG. 54.—Damage to the foundations of a temporary government building at Washington, D. C., by subterranean termites native to the United States; damage to a book in an infested building; the winged termite which appears only once a year; and the ant-like worker which is the wood destroying form and which always remains hidden within wood in galleries in the earth or in earth-like shelter tubes.

these colonies, or nests, both wingless and winged mature individuals are produced. The brownish or blackish, elongated, slender, antlike, colonizing, sexual adults (Fig. 54) with long white wings, unlike the other forms,

have functional eyes, and their bodies are able to endure full sunlight. These migratory males and females appear normally every year for a short period in large numbers, in a "swarm," to establish new colonies.

There are three stages in the life of white ants: the egg, the immature form (nymph), and the mature individual (including sterile workers (Fig. 54), soldiers, and the various fertile, reproductive forms).

Since termites are soft bodied, they always conceal themselves within wood, in the earth, or within their earthlike, carton shelter tubes (Fig. 55). The grayish-white, soft-bodied, wingless, sterile "workers" are in reality the destructive form and occur in the greatest numbers. These workers make the excavations occupied by the colony and enlarge and extend them as the colony increases. They live underground or within the wood, are blind, and shun the light; as a result, they are rarely seen.



(Courtesy Bureau of Entomology.)

FIG. 55.—Earth-like shelter tubes constructed up over a concrete foundation wall to reach wood forms under stamp vaults at Post Office, Federal Building, Honolulu, Hawaii.

No workers are present in colonies of "dry-wood" termites, but the young perform the duties of workers.

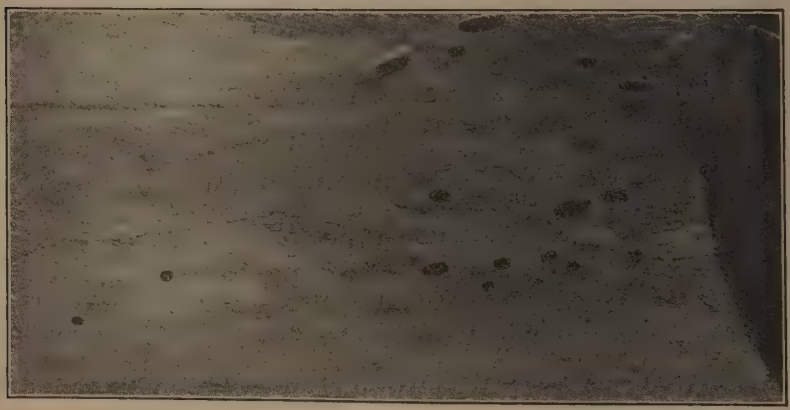
The sexual forms are of several types (Fig. 56) and are the parents of the colony.

TERMITES IN THE UNITED STATES

Termites are by no means restricted to tropical countries; they are serious pests in temperate regions, also. Termites have always been present in the United States, living on trees in the forests and on vegeta-

(*Courtesy Bureau of Entomology.*)

FIG. 56.—Three types of female reproductive forms or "queens" of a subterranean termite, each type has a male of corresponding form; (*a*) queen developed from the winged adult, or macropterous type; (*b*) the short wing pad or brachypterous form; (*c*) the wingless or apterous form. When the normal, monogamous form (*a*) dies many of either of the other types which are polygamous take her place. It is useless to attempt to destroy a termite colony by hunting for and killing the queen—the brood or young must also be destroyed.

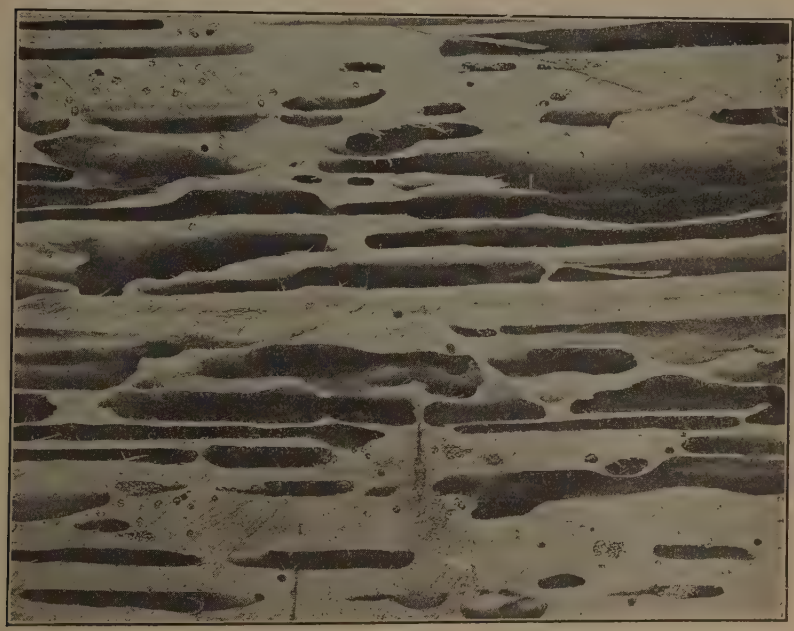


(*Courtesy Bureau of Entomology.*)

FIG. 57.—Entrances holes of dry-wood termites burrowed directly into wood, these holes are about the size of BB shot.

tion in the plains. With the clearing of the forests and cultivation of the fields by man, the natural habitats of these insects have been destroyed; and more extensive building operations have resulted in a further disturbance of the balance of nature. Termites have been driven to attack the buildings and crops of man in their search for shelter and food.

Termites of two distinct types occur in this country, namely, those subterranean in habit and the non-subterranean or dry-wood termites. The former burrow through the soil and attack wood indirectly from the earth, with which they must maintain contact to obtain the moisture so necessary to their life. They usually follow the grain in eating wood



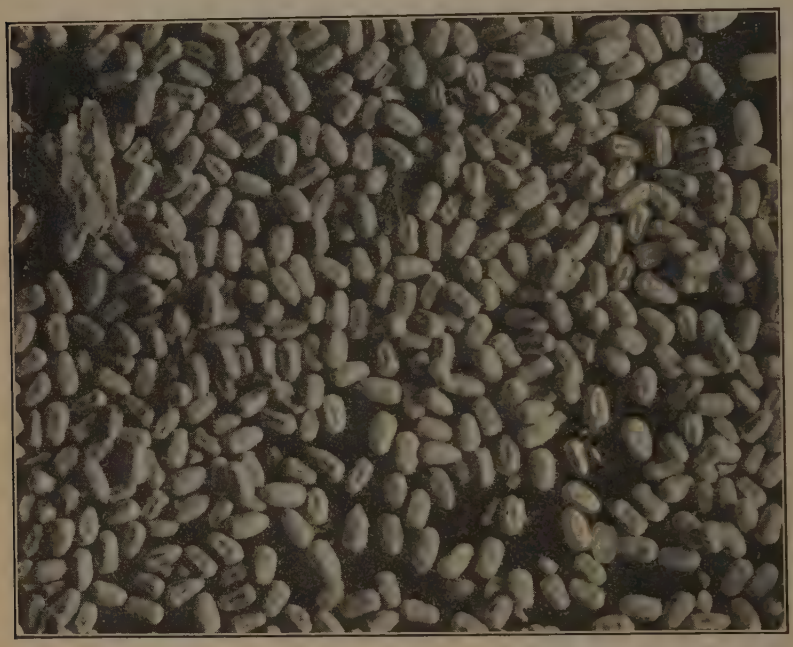
(Courtesy Bureau of Entomology.)

FIG. 58.—Rafter in "adobe" building in Arizona burrowed by dry-wood termites; note the chambers running across the grain of the wood, and the pellets of excrement in some of these burrows.

and honeycomb it. Subterranean termites are widely distributed throughout the United States, and they damage buildings in nearly every state (Fig. 54). They can seriously and structurally weaken buildings in a short period of time.

Non-subterranean termites never burrow in the earth but fly to and attack wood directly; they do not require much moisture and survive in wood containing less than the normal 12 to 15 per cent moisture of air-dried wood; they excavate large chambers in wood (see Figs. 57, 58, and

59) and do not follow the grain. These dry-wood or "powder-post" termites are not widely distributed, and their damage to buildings occurs only in that half-moon of country south of a slack line from Norfolk,



(*Courtesy Bureau of Entomology.*)

FIG. 59.—Impressed pellets of fine, digested, excreted wood expelled from infested wood by dry-wood termites; these pellets serve as a warning of infestation.

Virginia, to San Francisco, California. This type of termite cannot structurally weaken buildings so rapidly as can subterranean termites.

TERMITE DAMAGE TO BUILDINGS

Lack of information as to the destructiveness of our 42 different species of termites and as to their wide distribution throughout the continental United States often permits buildings to be erected with untreated woodwork directly in contact with or improperly insulated from the ground, thus leaving the way open for the entrance of ground-nesting or subterranean termites.

In consequence of such improper construction, termites burrow into the wood and often cause great damage to the woodwork and contents of the building before their presence is detected. It is a real hardship when a man on a moderate salary, who has made a large initial outlay on a new house, is forced after one or two years to expend several hundred additional dollars so to reconstruct the building as to eliminate termites. The

cost of repairing termite damage and preventing further attack would be far greater than the original cost of precaution.

Despite popular opinion, practically all the termite damage in the United States is done by native species; and much serious damage occurs throughout the eastern United States, the Gulf states, the Southwest, the central West and the Pacific Coast. Damage by termites in the "corn belt" of the central Western states is almost as serious as in some of the Southern states. Such damage occurs not only in cities but also in rural regions.

In the tropical possessions of the United States, different and more destructive termites occur, and continental United States is being closely guarded against their introduction.

THE FOOD OF TERMITES

The chief food of termites is cellulose, and they obtain it from living and dying vegetation; termites are among the few forest insects that attack both live and dead forest trees. In the intestines of most termites is a living fauna and flora of great diversity, present in enormous numbers. Protozoa (*Flagellata*), amœbæ, spirochætes, and fungi occur. Some of these protozoa contain enzymes which digest the cellulose of wood for the termites; without the protozoa the termites cannot live.

TERMITE-RESISTANT WOODS

So far as is known there is no species of tree in the world the wood of which has proved to be absolutely immune to attack by termites. Nevertheless, the heartwood of certain trees is very resistant to such attack.

Among the more resistant commercial woods tested by the Bureau of Entomology are teak (*Tectona grandis*) and sal (*Shorea robusta*) of India; cypress pine (*Callitris robusta*) and camphor wood (*Cinnamomum camphora*) of the Orient; redwood (*Sequoia sempervirens*), incense cedar (*Libocedrus decurrens*), yellow cypress (*Chamæcyparis nootkatensis*), western red cedar (*Thuja plicata*), and species of the junipers (*Juniperus spp.*) of the United States.

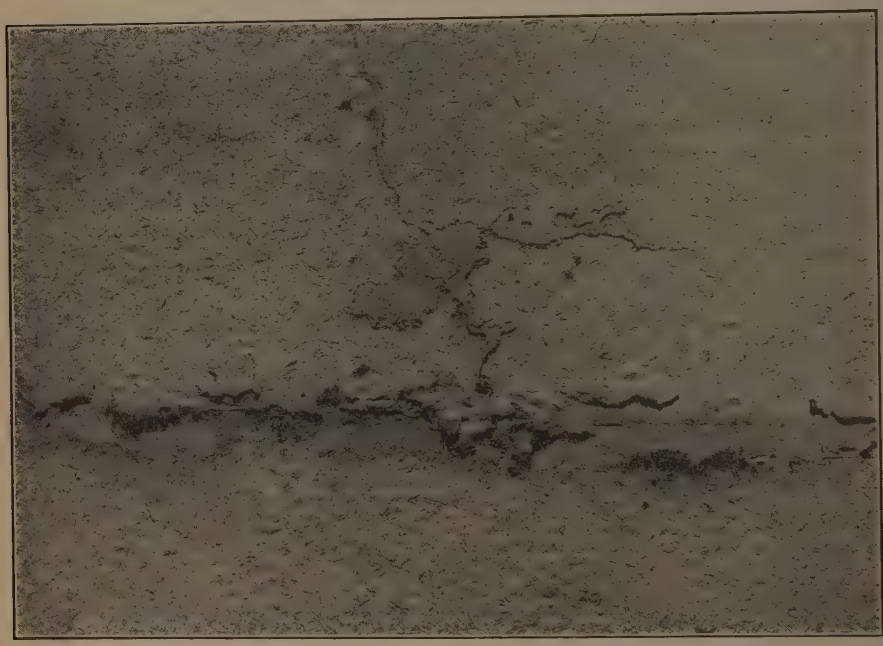
Certain chemical constituents present in the wood render it resistant. Stakes of longleaf pine (*Pinus palustris*) of Texas, cut from butt logs having a large resin content (locally called *fatwood* or *lightwood*), have remained unattacked by termites to date, although set in ground exposed to their attacks in 1913; whereas ordinary pine wood is very susceptible to attack by termites.

In view of the fact that but few termite-resistant woods occur in the world, it might be more practical to use commercial woods grown in the United States impregnated with standard chemical wood preservatives rather than attempt to obtain termite-resistant woods.

EXPERIMENTS WITH WOOD PRESERVATIVES

Since 1912, the Bureau of Entomology[1] has been conducting experiments with various chemical wood preservatives at Falls Church, Virginia, to determine which are the most effective in protecting wood against attack by termites. Experiments in chemical treatments are also being made with wood pulp and fiber products, such as wall board and the various composition boards, all of which are subject to termite attack.

In addition to the tests conducted in continental United States, supplementary tests were begun in 1924 on Barro Colorado Island, Canal



(Courtesy Bureau of Entomology.)

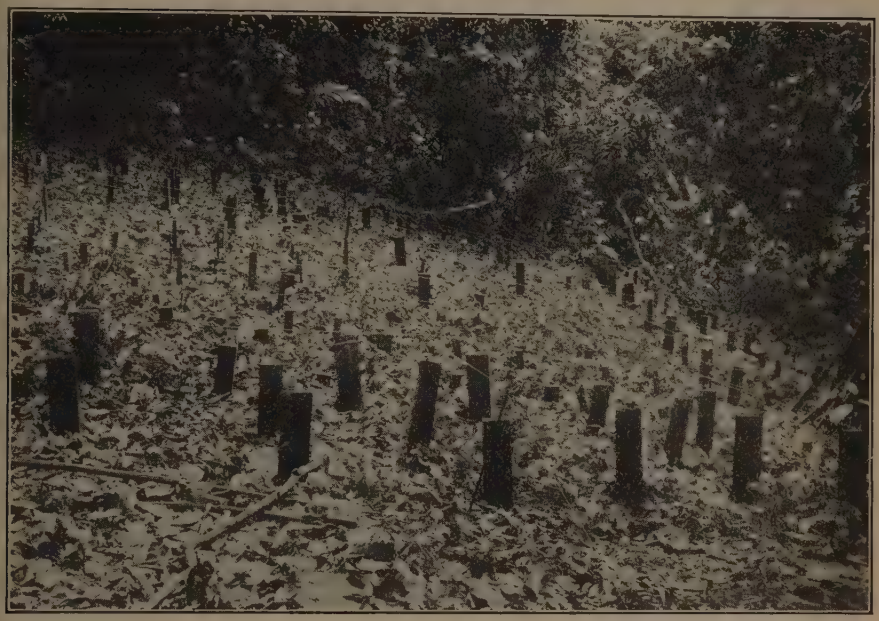
FIG. 60.—A section of fiber board showing damage by dry-wood termites. This board was nailed to rafters in a building at Panama and the termites penetrated the celotex after having first eaten through untreated wooden rafters.

Zone, Panama. Chemical preservatives are being tested not only for timber in contact with the ground, but also for interior woodwork, cabinet work and furniture (Figs. 60, 61, and 62).

To date, the most effective chemical preservative treatment for timber in contact with the ground is impregnation with coal-tar creosote. For timber not in contact with the ground, impregnation with zinc chloride has proved most effective. These are the standard chemical preservative treatments recommended by the American Wood-Preservers' Association.

These experiments are still underway and probably will be continued for many years, in the endeavor to discover more effective and cheaper preservatives.

[1] U. S. Department of Agriculture.



(Courtesy Bureau of Entomology.)

FIG. 61.—A portion of tests of timbers impregnated with chemical wood preservatives on Barro Colorado Island, Canal Zone, Panama, to determine the relative resistance of methods of impregnation and chemical preservatives in protecting wood from attack by termites or white ants. This site is a small cleared patch in a tropical jungle where many species of wood destroying termites occur.

(Courtesy Bureau of Entomology.)

FIG. 62.—View of tests of soluble salt wood preservative treatments to protect wood such as interior woodwork and furniture from attack by dry-wood termites. The test specimens are suspended from the roof of a shed by wires; the roof protects the treated wood from exposure. The shed in which these tests are being conducted is on Barro Colorado Island, Canal Zone, Panama.

TERMITE DAMAGE TO BUILDINGS DUE TO IMPROPER CONSTRUCTION

Most of the damage done to buildings by termites is directly due to improper methods of construction. Despite popular opinion, the age of the building does not determine whether or not it is liable to termite attack, since newly constructed buildings are often badly damaged by termites. It is not, furthermore, the type or kind of construction material used, but the manner in which it is utilized, that will lead to or prevent termite damage. Wood, masonry, concrete, brick, hollow tile, stucco, and even rammed earth can all be used so effectively that a building will not be attacked.

How Termites Infest Buildings

The principal methods by which the subterranean types of termite infest buildings (Fig. 63) are:

Entering untreated wood or fiber products in basements, cellars, or the foundations of buildings, where termite damage is most likely to start.

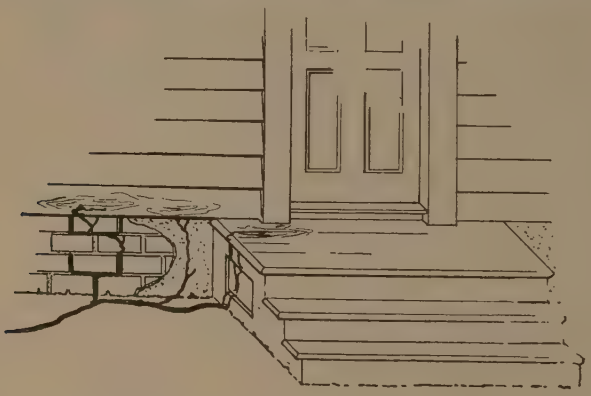


Fig. 63.—Principal methods by which the subterranean types of termite infest buildings.

Penetrating masonry walls where improper grades of mortar have been used in foundations, and working up through the interior of the walls.

Crawling up over impenetrable walls by means of earthlike shelter tubes and thus infesting buildings.

PROTECTION OF BASEMENT CONSTRUCTION ESSENTIAL

It is highly desirable, where practicable, to use treated wood in foundations, cellars, and basements (including basement floors) and to eliminate fiber and composition boards and other materials containing cellulose.

Untreated wood, however, may be used safely in buildings where the chief damage is by subterranean termites, if it is raised a suitable distance above possible soil contact, by rock, concrete, or brick foundations made

with standard grades of mortar or suitably capped, and if metal shields are put on to shut off passage tubes.

INSULATION AGAINST SUBTERRANEAN TERMITES

The specific against subterranean termites is "insulation" of all untreated woodwork from contact with the ground; this can be accomplished by the use of properly capped or sealed stone, concrete or brick foundations, and concrete lower flooring, or the use of foundation timbers impregnated with coal-tar creosote; and by means of metal termite shields. Nearly all of the termites which do serious structural damage to buildings in the United States are of subterranean habit; if they can be kept from reaching woodwork from the ground, they cannot survive in the building. Also, if present in the woodwork of a building after all untreated wood (such as joists, wooden floors, and sills) has been removed from contact with the ground, they will die out, *i.e.*, dry up, even if they have penetrated to the height of several stories in the building. They have been cut off from that which is necessary to their life, namely, their moisture supply in the ground.

IMPREGNATION AGAINST NON-SUBTERRANEAN TERMITES

Where, in addition to the subterranean variety, there are also termites that attack wood directly and do not burrow in the ground, only woodwork impregnated with standard preservatives should be used for exterior and interior construction. Windows, doors, and ventilation openings should be screened with 20-mesh non-corroding metal screening, particularly windows in attics and basements.

Impregnation with coal-tar creosote is the most effective treatment for foundation timbers that are to be set in contact with the ground; but for interior woodwork not in contact with the ground, impregnation with zinc chloride is recommended; wood so treated can be finished and painted.

BUILDING-CODE MODIFICATION

One of the simplest and most effective methods of preventing termite attack on the woodwork of buildings is to modify the building regulations or codes of various cities so as to include a few simple specifications in the mandatory section of the code. Recently, the Bureau of Entomology, of the United States Department of Agriculture, has been widely advocating such modification of city building regulations. Termite-proofing building campaigns have been carried on in all sections of the country where termite damage to the woodwork of buildings is serious, similar to the campaigns conducted by the Public Health Service in rat-proofing buildings. Indeed rat proofing, fire stops, and the prevention of decay and insect damage can all be effected by proper methods of

building construction. The aim of the Bureau of Entomology[1] is to have standardized specifications uniform in building codes throughout the country. In rural regions where there are no building codes, or chambers of commerce, the educational work may be conducted by prominent citizens, organizations, or with the help of county agricultural agents. For demonstration, model termite-proof buildings have been erected in the Canal Zone, Panama; and similar buildings are to be erected in the United States to serve as object lessons showing that buildings can be so constructed as to prevent termite damage.

The suggestions for inclusion in mandatory city building codes, are as follows:

Building Code Provisions for Termite Protection

Wood or fiber products, when not impregnated with an approved preservative, shall not be placed in contact with the earth, or within 18 in. thereof, excepting wood columns or posts over a concrete floor, which columns shall be provided with non-corroding metal or concrete base plates or footings 6 in. above the floor. This applies to steps, which shall be laid over a concrete base projecting at least 6 in. beyond the supports of the steps.

Timber to be used in contact with the earth shall be thoroughly impregnated with coal-tar creosote or other equivalent preservative, by a standard pressure process. Timber should be completely framed before treatment, whenever possible; but when cutting after treatment is unavoidable, the cut surfaces shall be thoroughly coated with coal-tar creosote or other equivalent preservative.

Masonry foundations and footings should be laid in portland-cement mortar. Foundations built up of masonry units, whether hollow or solid, shall be capped below woodwork with at least 1 in. of portland-cement mortar, or mortar and slate, or solid or jointed non-corroding metal, or other equally efficient seal (Fig. 64).

In the case of frame buildings, a metal termite shield shall be provided, continuing completely around the top of the masonry foundation, including all pillars, supports, and piping, below the woodwork of the building, on both the inside and outside surfaces. Such a shield may be formed of a strip of non-corroding metal (such as copper, zinc, or an alloy of copper 28 per cent, nickel 67 per cent, iron, manganese and silicon 5 per cent) firmly inserted in the surface of the masonry, or between the foundation and the wood, with the projecting edge bent downward at an angle of 45 deg., and extending horizontally at least 2 in. from the face of the foundation (Fig. 65). In masonry buildings this shield can be inset in the masonry at a height at least 18 in. above the ground.

Floor sleepers or joists imbedded in masonry or concrete, or laid on concrete which is in contact with the earth, shall be impregnated with an approved preservative (Fig. 66).

Expansion joints between concrete floor and wall shall be filled with liquid asphaltum, and the right-angle joint covered with a sanitary cement mortar or portland-cement concrete finish, on an arc at least 2 in. in length.

The ends of wooden beams or girders entering masonry or concrete shall not be sealed in but shall be provided with boxes affording an air space at the end of the piece of not less than 1 in. at side of member, unless the ends of such timbers are impregnated with coal-tar creosote or other approved preservative.

Where there are spaces under floors near the earth, they shall be excavated so that there will be no earth within 18 in. of the wood, and they shall be provided with

[1] U. S. Department of Agriculture.

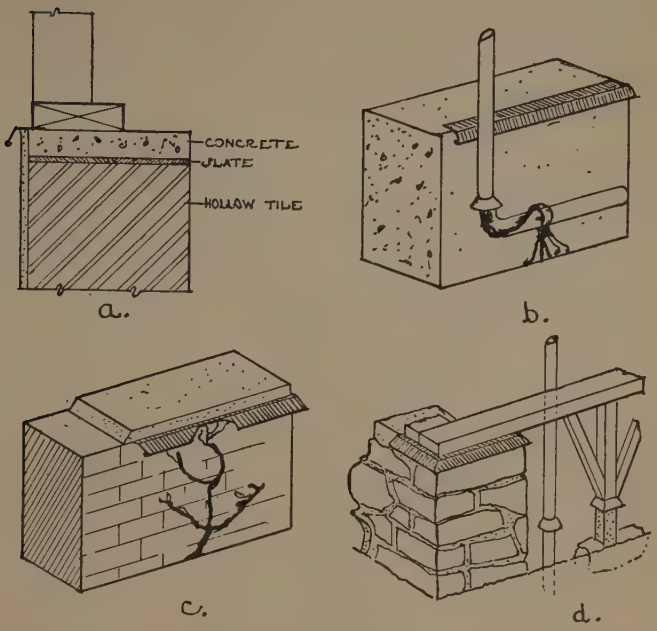


FIG. 64.—The insulation of hollow and solid masonry foundation units against termites: (*a*) foundation wall of hollow tile surfaced with stucco, showing metal termite shield in place and how the top of the wall is capped with sheet slate and concrete; (*b*) concrete wall with termite shield at top and horizontally laid piping fitted with metal shield above bend to shut off termite tubes; (*c*) brick wall with termite shield and capped with concrete; note how the shield mechanically blocks the earth-like shelter tubes of the termites; (*d*) stone wall with termite shield and capped with concrete and wooden posts insulated from the ground with base stone and concrete block. Note termite shield on post and piping.

(*Courtesy Bureau of Entomology.*)

FIG. 65.—Two views of metal termite shields in place in a building at Honolulu, Hawaii.

cross ventilation. The ventilation openings shall be proportioned on the basis of 2 sq. ft. for each 25 lin. ft. of exterior wall, except that such openings need not be placed in front of such building. Each opening shall be provided with 20-mesh non-corroding metal screening, including windows in attics.

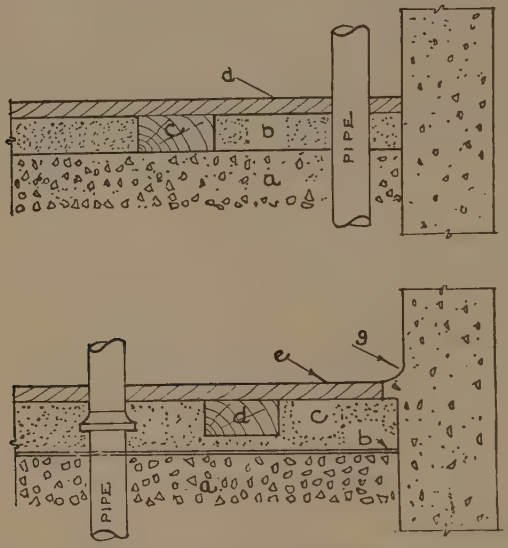


FIG. 66.—*Top*, improperly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, 3 in. thick, but with many crevices and holes; *b*, solid, dense concrete, 2 in. thick; *c*, 2- by 4-in. untreated wood sleeper set in moist concrete over the grout; *d*, 1-in. pine flooring nailed to sleepers.

Bottom, properly constructed concrete flooring: *a*, Gravel or cinders loosely cemented with coarse concrete, but with many crevices and holes; *b*, asphalt waterproofing $\frac{1}{8}$ in. thick; *c*, dense concrete, 3 in. thick; *d*, 2- by 4-in. treated wood sleeper set in a groove in concrete which insulates it from termites in the earth; *e*, 1-in. flooring nailed on sleepers; *f*, metal collar around pipe which runs down through the concrete (this collar should be soldered to the pipe and embedded in the concrete); *g*, shoulder of concrete at point of wall and concrete floor to avoid a right-angle connection and consequent cracking.

Where timber is used in roofs of the flat type, the roof, unless protected on the weather side with a covering impervious to water, shall have a slope and runoff sufficient to provide proper drainage.

All wood forms on foundations shall be removed from masonry work within 15 days; grading stakes should be removed before laying concrete floors.

These suggestions will probably add from 1 to 2 per cent to the initial cost of the building, but they are a form of insurance, not only to the householder but also to the person financing the building. Bankers have shown their understanding of this point by their willingness to loan more money or give a lower rate of interest to a home owner constructing a building in accordance with these provisions. The requirements are necessarily very brief, practical, and reasonable.

The chemical impregnation with standard preservatives of all woodwork to be used in a building where there is considerable damage by dry-

wood termites is recommended as a further precaution to persons who can afford the expense of it, but it increases the initial cost 10 per cent.

COST OF TERMITE-PROOFING SLIGHT

A few hundred dollars additional (2 per cent of the first cost) spent in the beginning in proper building construction may save thousands of dollars in repairs and replacements later. It is much simpler and cheaper to keep the termites out of a building than to get rid of them and repair the damage after they are once in, as this involves necessary repairs which may be too costly for the small householder. But certain methods of construction, that will prevent injury, are entirely practical.

In repairing buildings damaged by subterranean termites, the same suggestions apply as those made for the construction of new buildings. If these are followed, termites can be permanently removed from buildings where they are already working.[1]

Disconnecting Wood from the Ground.—This will save time and expense, especially in the case of old frame buildings where extensive repairs would not be practicable. When untreated foundation timbers are disconnected from contact with the soil, the termites in the other woodwork, furniture, and stored material in the building will die, even if they have reached the second or third floors. Timbers structurally weakened so as to endanger the building, or woodwork that is disfigured, of course, should be removed. If the wood is kept moist by some other means, however, such as water leakage, the termites will continue to work. This applies especially to damp corners of basements near outside water pipes, bathrooms, kitchens, and the like.

Wood floors laid directly on the ground, or on tar or tar paper, or on beams on the ground, or set in concrete should be removed. There should be a layer of concrete, or of some other artificial stone, effectively sealed with proper mortar or concrete, between the earth and the wood.

Capping and Facing.—A frame building need not be raised or jacked up to cap the wall, but the upper tier of bricks may be removed, a few at a time, and the wall capped.

Where poor grades of mortar have been used in masonry walls below the ground, it may be necessary to coat the outside or inside of the wall with portland cement or concrete, to prevent termites from boring through.

Metal Termite Shields.—These shields can be inserted over or in masonry foundations of buildings already constructed.

[1] Fumigation with poisonous gases, drenching the wood with poisons in solution, or the use of powdered insecticides are of no permanent value against subterranean termites in buildings, as the building will be continually reinfested by other termites coming up from the ground.

REMEDIES TO BE EMPLOYED AGAINST NON-SUBTERRANEAN TERMITES

Fumigation.—Fumigation with the very poisonous hydrocyanic-acid gas will kill dry-wood termites infesting the woodwork of buildings and boats. This gas is very dangerous, and fumigation with it should be done only by an expert.[1] The infested wood should be exposed as much as possible, and it may be necessary to open up some of the structure.

Where several stories of buildings are affected, the windows should be sealed, and after the fumigation is completed, the rooms should be aired by opening windows with cords from the outside. The usual proportions should be employed—that is, 1 oz. (avoirdupois) of sodium cyanide to 1½ fluid oz. of sulphuric acid and 3 fluid oz. of water; and 12 oz. of the cyanide used per 1,000 cu. ft. of room capacity, instead of the 10 oz. usually recommended, will make the gas 20 per cent stronger. This fumigation will result in the death of the insects within the wood. The fumigating should be done just before the winged adults fly. At that time these insects are in the outer layers of the wood where they are readily accessible, and fumigation will destroy large numbers of them, thus greatly reducing the source of reinfestation.

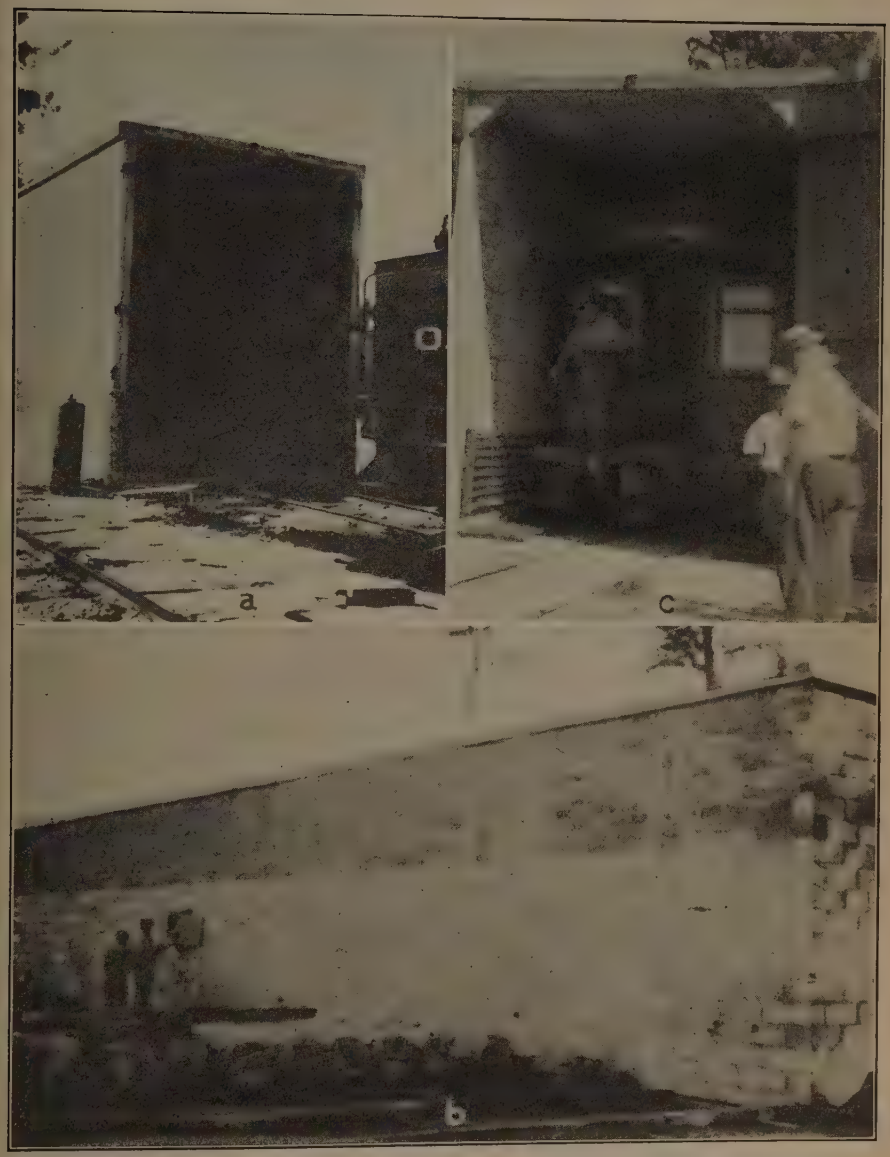
Furniture infested by these termites can be fumigated in steel cylinders with carbon-bisulphid gas or can be given heat treatments.

Heat.—Temperatures of 130° F. and over can be utilized in killing termites infesting the woodwork of railroad cars, furniture, etc. In Hawaii, a chamber of reinforced concrete large enough to contain a passenger coach or two freight cars run in on rails was specially constructed (see Fig. 67). The sides of the interior were equipped with coils of piping, live steam from a locomotive was utilized, and at 90 lb. pressure it was possible to subject the infested wood to a temperature of 150° F. for at least 1½ hours. The heat was gradually raised, and temperatures could be determined from a thermograph on the exterior of this building. The paint or varnish finish on the wood was not injured by the heat.

Such a chamber should be located at all ports where wood infested by dry-wood termites or other borers is liable to be introduced, and the infested wood subjected to a heat treatment, which is more reliable than fumigation.

Insecticides or Poisons.—Poisons can be used to kill non-subterranean termites within the wood. Insecticides useful for this purpose are orthodichlorobenzene, or a 10 per cent solution of kerosene emulsion poisoned by dissolving 1 oz. of sodium arsenite in each gallon of water used for diluting stock mixture of kerosene emulsion, or miscible oils. The infested wood is drenched with the insecticide by swabbing with a saturated rag or mop; several treatments may be necessary, and careful watch should be maintained until it is certain that all the termites are dead.

[1] Howard, L. O. and C. N. Popenoe, "Hydrocyanic-acid Gas against Household Insects." *U. S. Dept. Agr., Farmers' Bull.* 699, Washington, D. C., 1916.



(*Courtesy Bureau of Entomology.*)

FIG. 67.—Views of the heat chamber at Honolulu, Hawaii, (*a*) showing the door and the locomotive from which heat is furnished by means of live steam through pipes at 90 lb. pressure; (*b*) the side of the chamber which is 75 ft. long showing the location of the thermograph on the exterior; (*c*) a passenger car ready to be brought out from the heat chamber, the iron work on the car being so hot that it cannot be touched. Such chambers should be constructed at all seaports where dry-wood termites or other wood borers are likely to be introduced.

In Hawaii, dry paris green, blown with a bellows into galleries in infested wood, has been used successfully; where moisture is present, this powder cakes and becomes ineffective.

Impregnation with Wood Preservatives.—In regions where much damage is caused by dry-wood termites, the buildings should be screened, and all woodwork used in buildings should be impregnated with a standard chemical wood preservative to prevent attack.[1] This impregnation should be made before the wood is placed in the structure and should be given to wood cut to exact necessary dimensions. In case the impregnated wood is to be framed after treatment, the cut surface should be given a brush or dipping treatment with the hot chemical. Such impregnated wood or timber can be purchased at retail lumber yards, in various sections of the United States.

For interior woodwork and furniture, an impregnation giving an average absorption of ¾ to 1½ lb. of dry zinc-chloride salt per cubic foot is recommended. Sodium fluoride and chlorinated naphthalene, while more expensive, are also effective preservatives for timber not to be used in contact with the ground, where moisture would cause leaching. These chemicals could be adapted to special, but more limited, uses.

Wood-pulp or fiber products, such as the various wood-fiber-processed or composition boards and cane-fiber boards (Fig. 68), can be protected from termite attack by adding certain poisons, such as crude carbolic acid, to the pulp or laminated boards in the course of manufacture. Available poisons for this purpose are crude carbolic acid at the rate of 1 gal. to 1,000 sq. ft.; bichloride of mercury at the rate of 49 oz. per 1,000 sq. ft.; copper sulphate at the rate of 113 oz. per 1,000 sq. ft.; sodium fluoride, sodium fluosilicate, sodium dinitrophenolate, or chlorinated naphthalene are also effective poisons for protecting such products from attack by dry-wood termites.

DEMONSTRATION TERMITE-PROOF BUILDING

On Barro Colorado Island, Canal Zone, Panama, a model, demonstration, termite-proof building (Fig. 69) was erected in cooperation with the American Wood-Preservers' Association during August, 1926. This building was constructed entirely of wood, all of which had been impregnated, before framing, with such effective standard preservatives as coal-tar creosote and zinc chloride; the treatments were made by both the full- and the empty-cell pressure processes of impregnation. The treatment selected in each case was that most suitable for the position of the timber or lumber in the structure. Thirty species of wood-destroying termites occur on Barro Colorado Island, and to date none of them has attacked this building.

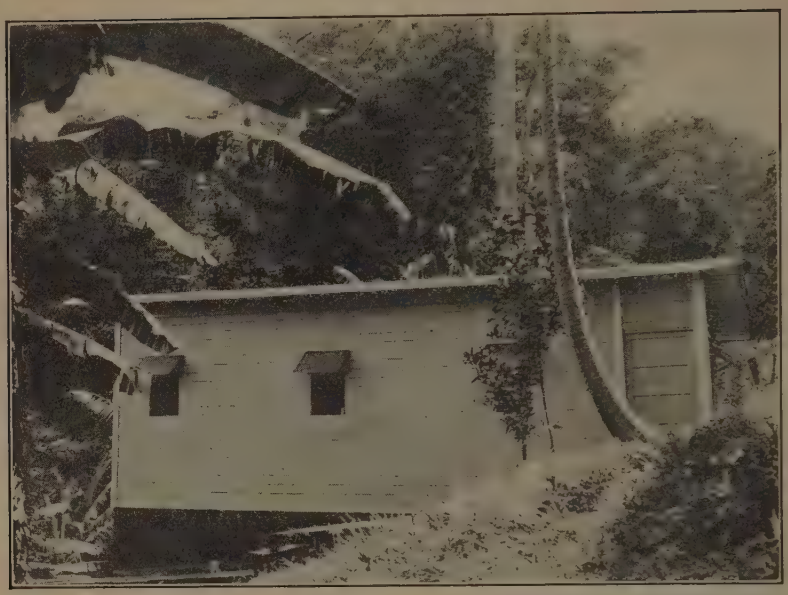
[1] SNYDER, T. E., "Tests of Methods of Protecting Woods against Termites or White Ants." *Bull.* 1231, *U.S. Dept. Agr.*, Washington, D.C., 1924.

(Courtesy Bureau of Entomology.)

FIG. 68.—Pressed wood-pulp tile mined by subterranean termites infesting a building at Biloxi, Mississippi.

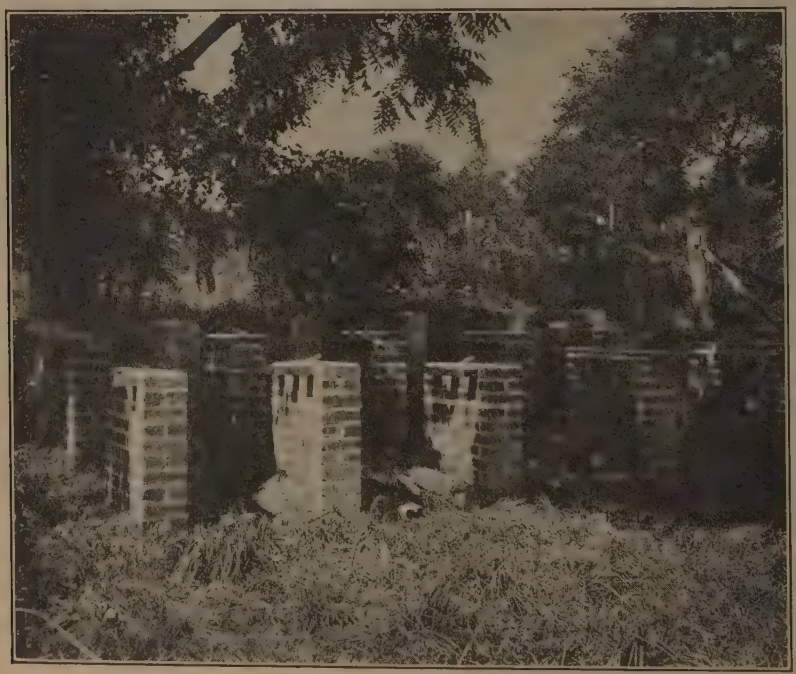
(Courtesy Bureau of Entomology.)

FIG. 69.—Model termite-proof building constructed entirely of timber impregnated with standard wood preservatives located in a tropical jungle on Barro Colorado Island, Canal Zone, Panama. The timber and finish, in this building were impregnated with the preservatives most suitable for their position in the building. Many species of wood-destroying termites occur on this island.



(*Courtesy Bureau of Entomology.*)

FIG. 70.—Building constructed on Barro Colorado Island, Canal Zone, Panama, of close-grained heartwood redwood (*Sequoia sempervirens*) from the Pacific Coast of the United States to test its resistance to attack by termites.



(*Courtesy Bureau of Entomology.*)

FIG. 71.—Test brick and concrete walls constructed at Fall Church, Virginia; mortars of various compositions are being tested in these walls as well as different compositions of concrete to determine the most effective in preventing attack by termites or white ants.

On this island, during April, 1927, several buildings and a tower were also erected of redwood (*Sequoia sempervirens*) from the Pacific Coast, to determine the resistance to attack by termites of a special grade of close-grained heartwood redwood (Fig. 70). None of these structures has been attacked up to the present time.

TESTS OF MORTARS FOR FOUNDATION WALLS

Tests of mortars and concretes of various different chemical and physical combinations are being conducted by the Bureau of Entomology,[1] to determine the most effective combination for preventing penetration by termites in masonry foundations below the surface of the ground.

(Courtesy Bureau of Entomology.)

FIG. 72.—Condition of the mortar after 6 months' test where an improper grade had been used.

Certain termites, subterranean in habit, are able to dissolve certain grades of lime mortars. At Falls Church, Virginia, 16 test walls, or panels, were constructed in August, 1926. Other similar test walls have been built by the Bureau of Standards at Washington, District of Columbia, and by the State Entomologist at Urbana, Illinois, during 1927, in cooperation with the Bureau of Entomology. These tests will be rather long-time tests, although certain grades of mortars have already failed (Figs. 71 and 72).

[1] U. S. Department of Agriculture.

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CHAPTER VIII

LIGHT BUILDING CONSTRUCTION

The three types of wood framing in common use are designated as *balloon, braced,* and *western.*

Plates 1, 2, and 3 illustrate approved methods of framing these three types of structure.

Balloon-framed Buildings.—These are buildings in which the supporting studs extend from the foundation to the eaves, a ribbon or ledger board being let into the studs to form the support for the joists.

The balloon type of framing, with its modifications, is today the commonest type of construction throughout the country. It is the outgrowth of pioneer methods during the last century, when speed and economy were the important results to be achieved. This is the only distinctive type of light building construction in which the studs extend from the basement wall plate to the plate at the eaves; and, of course, the long studs can be erected much more rapidly and economically than can the shorter studs used in either of the other two types of framing. Experience also indicates, moreover, that where a stucco finish is to be employed, cracks are less likely to occur when the wall studs are continuous from the foundations to the eaves; the insertion of horizontal timbers at the floor lines, as in other methods of framing, gives more opportunity for vertical shrinkage and consequent stresses in the enveloping stucco surface. In balloon-frame construction, the omission of floor headers and of fire stops, to save the builder a few dollars, permits heat losses by free air circulation and removes a possible means of checking a future fire; lack of corner braces impairs rigidity, unless the sheathing is placed diagonally, and unequal settlement results from resting partition studs on the subfloor. These are common faults which must be guarded against in this type of framing.

Braced-frame Construction.—This type of frame was brought from Europe and adopted by early New England and Colonial builders. It survives today in some sections of the country and is an expensive though very satisfactory type of framing. Its characteristic feature is separate story framing. Solid corner posts extend from the foundation to the eaves, with the joists supported on heavy girts framed into the posts, the studs being cut in between the girts. Heavy knee braces are provided at all corners, at each floor level. This framing is unusually rigid, strong, and durable and is in every way adaptable to modern building needs.

The historic dwellings of New England, that are 200 or more years old, are of this type of construction.

This type of framing was developed because it required fewer timbers cut from the log and fewer joints in its assembly. The proper fitting of mortise-and-tenon joints with wood dowels and pegs was a slow, laborious task in those early days, and the work of hewing out a sufficient number of pieces for the framing of a building was tedious and difficult. Speedier production, more accurate manufacture, machine-made nails, and increasing labor costs led naturally to the development of a modified system of house framing and the perfecting of alternate types.

Western-framed Buildings.—In these buildings the supporting studs extend from the top of each tier of joists to the underside of the tier next above, the studs being provided with top and sole plates.

This type of construction is sometimes referred to as *platform-frame construction*, because the first floor is built on top of the foundation walls as though it were a platform, and the second floor on top of the first in a similar manner.

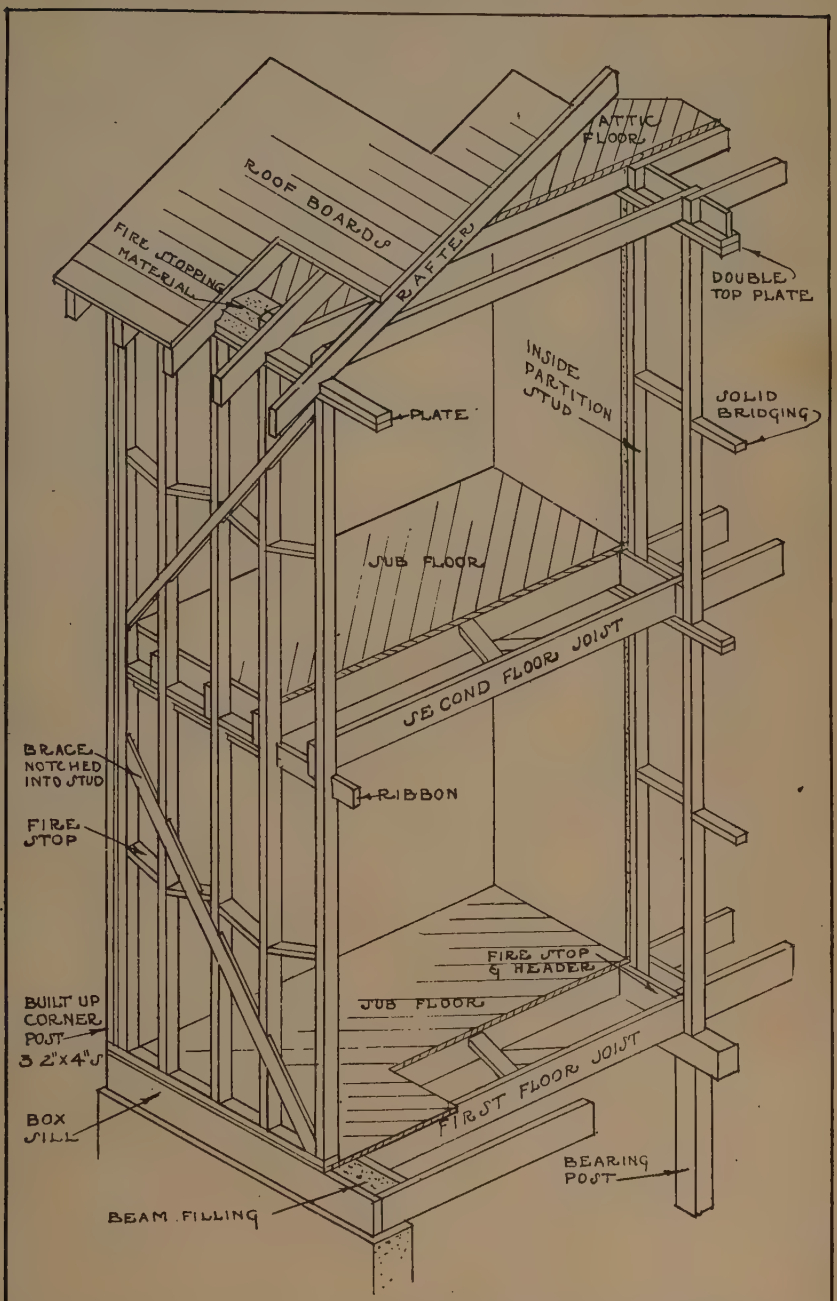
The type was developed to overcome the effects of unequal shrinkage (see p. 236) by using the same amount of horizontal lumber in both the exterior and the interior walls of the building. Since to accomplish this, however, it is necessary to increase the total amount of horizontal lumber in the building (and the consequent total shrinkage), the western frame today has only a limited use and is not recommended.

There is no hard-and-fast rule for designing, and it is difficult to draw distinct lines between these three types of framing, as modified in actual practice. Each type has its advantages; and each, if framed in accordance with the illustrations shown, will afford satisfactory results.

PLANS AND SPECIFICATIONS

Timber detailing differs from steel detailing, for there are no generally accepted standards for connections for lumber-built structures, as there are for steel-framed buildings. Every set of plans for a frame building should give enough information to make it possible to compute accurately the cost of construction; joints and connections should be shown or specified in sufficient detail to make possible accurate listing of the lumber items which are to go into the building.

A set of contract plans for a steel-framed building may be little more than diagrammatic sketches with sizes of members and stresses shown in other members, the details being left to be worked out in the shop of the contractor, subject to the approval of the engineer or architect. This method cannot be satisfactory in lumber construction. Such a thing as shop or detail plans for frame buildings is practically unknown. The contract plans, therefore, must be complete, with all details carefully worked out and not left to the discretion of the carpenter, who, many



BALLOON • FRAME • CONSTRUCTION

Plate 1

times, in his endeavor to improve on a detail but hazily indicated actually weakens the structure.

For the proper presentation of the work, there should be given a general plan, framing plans of all of the floors and the roof, wall elevations, cross-sections and longitudinal sections, elevations and sections of any special features, and details of all connections except the very simplest, which may be covered in the specification.

Drawings that are badly out of scale should never leave the office. This statement, of course, applies to all construction; but it holds particularly in lumber construction, as the carpenter is almost certain to scale some lengths of lumber. A general and comprehensive note should be placed on all structural drawings, even repeating certain important clauses in the specification. On the job the specifications may be lost; the plans are never lost. One note on the drawings is worth two clauses in the specifications.

CHOICE OF WOOD

The choice of wood for particular uses (see Appendix) is a matter of fundamental importance, because it affects both the cost and the utility of the building. The chief facts relating to the suitability of the various species of wood ordinarily used in building construction for the special needs encountered in this field are set forth in Chap. I. By the application of this information it is possible to secure desired results; but, besides understanding the properties of species which make them particularly suitable for certain uses, there are some principles associated especially with the requirements of use which have a direct bearing upon the choice of wood for special purposes.

Choice of species in practice must, of course, be modified by the availability of the most adaptable species in the locality of the building. The most suitable wood for the use intended may not be the most economical from a cost standpoint.

Strength and stiffness, for example, are necessary properties for framing lumber, which should also have good nail-holding properties and a minimum of shrinkage.

For sheathing, light low-density woods with correspondingly high insulating properties should be selected.

Outside trim and decoration require woods which possess certain special characteristics. For these uses, a variety of qualities must be considered, such as appearance, weather resistance, nail-holding power, paint-holding capacity, and the ease with which the wood can be worked.

Wood in contact with the ground should be durable and resistant to insect attack and decay. Treated timber should always be used close to the soil, or near moisture, unless a heavy durable species is selected for use at the one or two danger points in the building. If, however, ter-

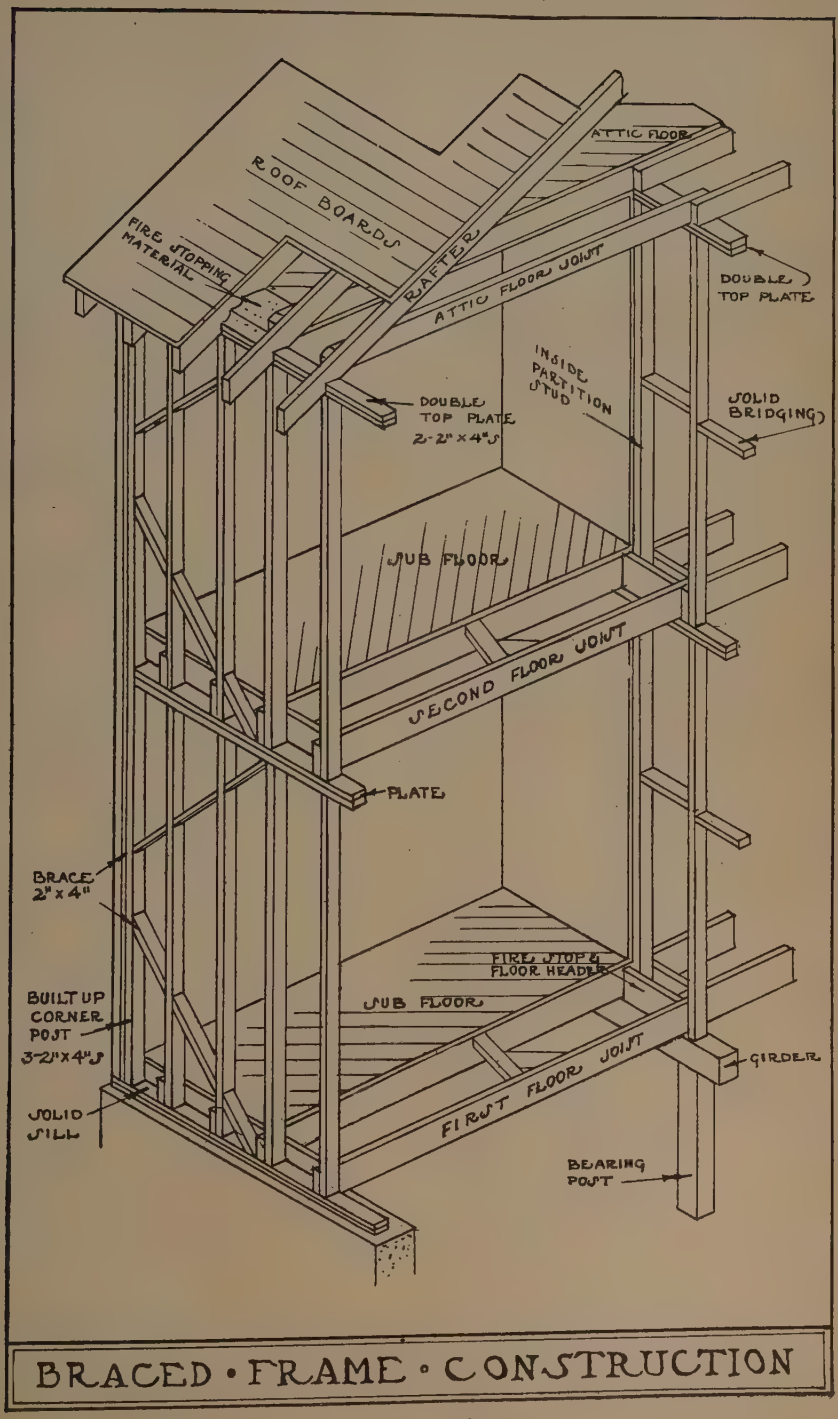

ROOF BOARDS
RAFTER
ATTIC FLOOR
FIRE STOPPING MATERIAL
ATTIC FLOOR JOINT
DOUBLE TOP PLATE
INSIDE PARTITION STUD
DOUBLE TOP PLATE 2-2" x 4"S
SOLID BRIDGING
SUB FLOOR
SECOND FLOOR JOINT
PLATE
BRACE 2" x 4"
FIRE STOP & FLOOR HEADER
BUILT UP CORNER POST 3-2" x 4"S
SUB FLOOR
GIRDER
SOLID SILL
FIRST FLOOR JOINT
BEARING POST
BRACED • FRAME • CONSTRUCTION

Plate 2.

mites are prevalent, the treatment of all lumber that is placed in or near the ground is absolutely essential, regardless of species.

A wood that is light, soft, durable, easily worked and molded, and free from the tendencies to warp, swell, and shrink should be used for all outside finishing. It should be free from objectionable oils and resins and should hold paint well. Most commercial species are generally available all over the country, but some of these species may be difficult to obtain in certain sections unless the user insists on getting what he wants. Architects and builders are urged, therefore, to insist upon obtaining information on the availability and price of those particular species which are best adapted to the use in question.

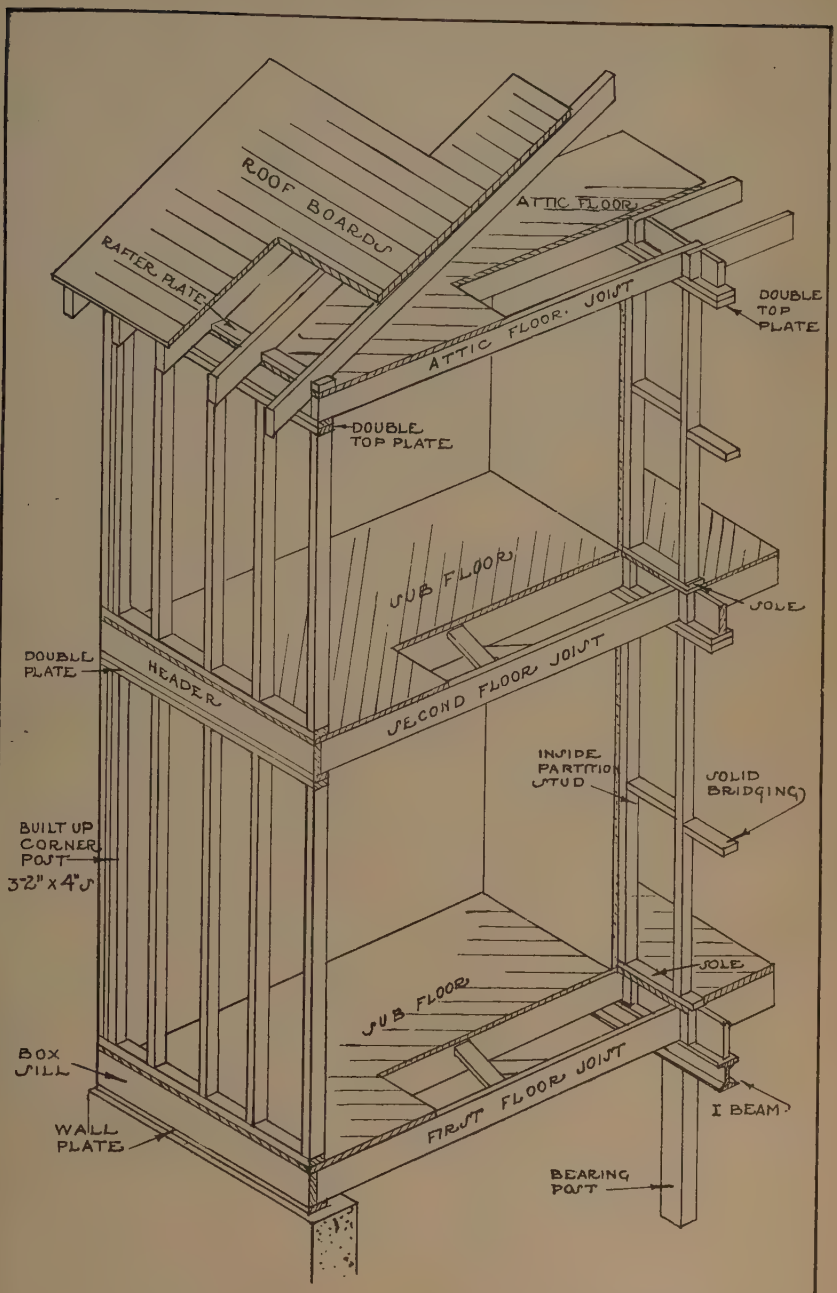
IMPORTANCE OF DRY LUMBER

Foundation settlement, of course, is the major cause of plaster cracks; but in the great majority of cases the drying and consequent shrinking of green lumber contribute to the development of unsightly cracks in both walls and ceilings. Insistence upon the use of dry lumber is the only way in which a careful builder can avoid the shrinkage and other difficulties which are bound to result from the use of green lumber (see discussion in Chap. I). Dry lumber costs but little more and prevents the troubles caused by loss of moisture after the lumber is in place in the building. Dry lumber also takes paint better than green lumber, and while not as easy to obtain today as it was 25 years ago, it can be had, if those interested will insist upon definite moisture limits in their lumber specifications.

Formerly, the lumber dealer, depending on slower transportation between the sawmill and retail lumber yard, and anticipating the lumber demands of his locality, was compelled to carry a much larger stock. As a result, the lumber had a chance to season a month or two or even longer, before being delivered and used.

Now, under modern conditions of quick transportation and high-ground rents, he carries a small supply, often only enough for 2 or 3 weeks. As a result, lumber goes more directly from the sawmill to the building, and air seasoning is minimized. In addition, there is always the chance that rainy periods will occur while the building is being erected. Consequently, it is rather uncommon for framing lumber when placed in a building to be so dry that it will not ultimately shrink considerably. This shrinkage, unless partly eliminated by proper design, may cause trouble later. Since lumber, in drying, shrinks mostly across the grain, as explained in Chap. I, horizontal lumber should be used in bearing only where necessary.

To overcome uneven settlement of floors, and to reduce the plaster cracks which result from unequal shrinkage, provision should always be made to insure as nearly the same settlement of interior bearing partitions and outside walls as can practicably be accomplished. This can be



WESTERN • FRAME • CONSTRUCTION

Plate 3.

done by making depth of interior horizontal lumber members in bearing as nearly as possible equal to the depth of horizontal lumber supporting members in the exterior walls. Exact equality is not usually practicable, but an approach to equality may be effected in balloon and braced framing by extending the bearing partition studs down between the joists to rest directly upon the supporting girder. In the western frame, equality is obtained by means of the platform construction, where all studding is placed on plates directly on top of joists. Similarly, if one end of a joist rests upon a concrete foundation, the other end should not be supported on top of a wooden beam, since the beam will shrink and lower that end of the joist, while the other end remains stationary.

As a step toward eliminating much of these shrinkage troubles, the lumber industry has recently adopted moisture content as a basis for determining the actual sizes of lumber sold. Lumber manufacturers associations are actively studying the question of proper moisture content for the various classes of lumber and will set up definitions of dryness as soon as practicable.

The determination of moisture content is neither a difficult nor a costly undertaking; it has already been discussed in Chap. I. To avoid the necessity of computations or any technical knowledge, however, kiln manufacturers offer at reasonable cost (approximately $60) the necessary unit, consisting of an electric oven and a delicate scale or similar apparatus, by which the moisture content can be quickly and simply determined. The equipment can be connected to the ordinary light socket. The specifying consumer, therefore, will have an easy means of determining whether or not the lumber he receives is satisfactory for the use intended, from a moisture-content standpoint.

To a certain extent, the dryness of lumber may be roughly estimated by visual inspection. Some lumbermen claim, also, that they can determine the moisture content to approximately 5 to 10 per cent by knocking the courses in a pile of lumber with a stick. If the lumber is dry it gives a sharp, ringing sound, while if it is green a sullen thud is produced. In other words, the dryer the lumber the sharper the ring. Also, wet lumber usually has a fuzzy surface, is pliable, and, when pulled, shreds off in strands. If the lumber is dried, it has a tendency to be brittle and to break off in pieces. These methods, however, should not be substituted for a mathematical determination of moisture content by means of test pieces.

It is, of course, important after lumber has been purchased and delivered, that care be taken in piling it, on the job, before it is used. It should be kept off the ground and every possible precaution taken to see that it is kept dry. It is especially important to see that window and door frames and other millwork are well protected from the weather between the time they are delivered and the time they are actually

installed. It is a common sight in a building operation to see face brick carefully covered with a tarpaulin, while nearby window frames are carelessly exposed to the elements.

IMPORTANCE OF FOUNDATIONS

Neglect of any of the following details usually results in poor economy, no matter what type of framing is used: Adequate masonry foundations should be provided, and all foundation walls should be built on solid bottom and carried to a sufficient depth to prevent heaving by frost action. Foundation walls enclosing cellars and basements should start at least 4 in. below the cellar floor and be carried to not less than 1 ft. above the finished grade line. In locations where ground water may rise above the basement floor level, or where surface drainage is inadequate, cellar or basement walls should be made effectively water-tight and, if necessary, drained with drain tile; this should be laid not higher than the top of the footing, and the trench backfilled with porous material. Some building codes provide that a course of slate must be worked into all walls to their full width, two courses above grade, and an additional course above footings where there is a basement. This prevents capillary action and secures an effective water stop. The importance of suitable provision at the bottom of walls to keep the load distribution within the carrying capacity of the soil should not be overlooked. It is also important to have sills secured to the foundation walls with bolts, especially in sections frequently visited by tornadoes or destructive windstorms.

GENERAL PRINCIPLES OF LIGHT FRAMING

In light framing, it is not necessary to develop the full strength of all members at the joints, for load-supporting members are seldom stressed to capacity in this type of construction. Joints, however, must be amply strong to transmit all loads and be rigid enough to prevent racking in the structure when it is subjected to wind and ordinary live loads. In certain regions, light earthquake shocks should be provided for, and, in general, strong joints and rigid, durable construction are essential.

Formerly, elaborate joints such as the mortise-and-tenon and tenon-and-tusk joints were in common use, but due to the high cost of present-day labor and the use of smaller sizes of lumber in building, such joints are now almost obsolete.

The old wrought-iron nail, which was expensive to make, was also a factor in the joining practices which prevailed up to the latter part of the last century. The advent of the wire nail, however, brought about changed methods in this field; now, most connections in light framing are nailed connections, although occasionally joints are notched. This

adds security when toenailing is resorted to, but the toenailed connection should be avoided wherever possible, as its strength is due solely to the nail-holding properties of the species of wood used and is, therefore, always doubtful.

The economical use of wood in framing involves both strength and stiffness. The strength of a beam varies as its width or breadth and as the square of its depth, and the load which it will sustain is dependent upon the character, size, and location of defects and the quality of the clear wood. A 2 by 8-in. joist, disregarding reductions due to planing and dressing to the commercial size of $1\frac{5}{8}$ by $7\frac{1}{2}$-in., would be four times as strong as a 2 by 4-in. joist when both are placed with the greatest dimension vertical. If these two pieces are placed on their sides, the 2 by 8-in. piece is only twice as strong as the 2 by 4-in. piece. On its side, moreover, the 2 by 8-in. piece will develop only one-fourth of the strength it would develop if placed on edge. These statements, which, of course, are based upon the formulæ of mechanics, indicate why beams are practically always used with the greater dimension vertical.

The stiffness, or resistance, which a beam offers to flexure, however, varies as the cube of its depth and is influenced but little by the grade of the material. For this reason, in selecting lumber for load-supporting members, such as floor joists, it is often possible to use a lower grade of lumber and a deeper joist, to compensate for the decrease in strength with grade, thus obtaining a much stiffer joist of equal strength, and at the same or less cost.

For example, in the use of southern pine No. 1 common for joists having a 12-ft. span and the usual 16-in. spacing and a 90-lb. live load with plastered ceiling, it will be found, from the table on page 263, under f = 1,200 lb. per square inch (see p. 114, paragraph 1), that a 2 by 10-in. joist is required to carry the load. This means 20 f.b.m. (feet-board measure) in a 12-ft. length.

On the other hand, if No. 2 common is used, with an allowable stress for safety's sake of 900 lb. per square inch, it will be found from the same table, under f = 900, that a 2 by 12-in. joist is required to carry the load, which means 24 f.b.m. per joist.

Now, No. 1 common had a mills sale price of $26.35 at Kansas City, Missouri, on Feb. 17, 1928. So that, for 20 f.b.m., the cost would be 53 cts. per joist; while No. 2 common could be purchased for $20.38, or 49 cts. per joist.

Accordingly, by using a lower grade lumber in a larger size, the needed strength could be obtained at a saving of about 8 per cent; and in addition, since stiffness varies as the cube of the depth, a greater stiffness, roughly equal to $\frac{(12)^3}{(10)^3} \times \frac{900}{1{,}200} = 1.29$, or about 30 per cent more than that obtained by using the smaller size, would result.

So that even if increased freight and labor charges on the larger size, should offset the saving in cost of material, there still would remain a gain in the degree of stiffness, which in floors is a very important item. On the other hand, if heavy timbers are considered in a design where strength in bending is the critical factor, it will frequently be found that an economy can be effected by using the best grades of lumber, at a higher price, but with less material. For example:

TIMBERS OF EQUAL CARRYING CAPACITY

Good No. 1 common, fiber stress 1,200 lb. Amount required say 960 ft. 8 by 12 (120 lin. ft.)		Structural grade, fiber stress 1,600 lb. Amount required say 720 ft. 6 by 12 (120 lin. ft.)	
Freight:		Freight:	
960 ft. @ 3,300 = 3,168 lb. @ 72 cts	$22.81	720 ft. @ 3,300 = 2,376 lb. @ 72 cts	$17.11
Labor putting in place:		Labor putting in place:	
960 ft. @ $15	14.40	720 ft. @ $15	10.80
Cost of freight and labor	37.21	Cost of freight and labor	27.91
Mill price 960 ft. @ $24	23.04	Mill price 720 ft. @ $35	24.48
Total cost in place	$60.25	Total cost in place	$52.39

Still another important consideration in framing is the laying out of houses and other buildings so that standard mill lengths of lumber can be utilized for floor joists, studs, girders, and other similar items. When this can be done without seriously affecting architectural considerations, appreciably lower material and labor costs will result. At times, a few inches' increase in story height or room width will accomplish this result and still permit the architect to adhere to his original plan; at other times, a decrease of a few inches in story height or in joist span may permit the use of lumber 2 ft. shorter. For example, a room 9 ft. 6 in. by 14 ft., with joists running in the short direction, would require 10 ft. 4 in. joists (allowing 4 in. at each end for studs and 1 in. for finish). These joists would have to be cut from a 12-ft. piece, whereas a decrease in the size of the room to 9 ft. 2 in. would make possible the use of 10-ft. joists.

SILLS

Besides being bolted into the foundation with ¾-in. bolts placed not over 8 ft., anchored from 18 to 24 in. into the foundation wall (see *Plate* 4), wood sills should be set in mortar so that they will be level and will provide an airtight joint between the sill and the masonry. The bottom of the sill lumber, and as much of the sides as may come in contact with mortar, should be covered with asphalt paint. The sill should be set back at least an inch from the outside of the masonry, to allow room for the sheathing and to give the desirable effect of solidity to the building. Sills should be run continuously from corner to corner of the building and

should be of one piece if practicable, halved at corners and spiked but never butted or mitred. Box sills, like those illustrated in *Plate* 4, are not so satisfactory as solid sills, because they have greater shrinkage possibilities and are more difficult to anchor satisfactorily to the foundation. Although they are an inherent feature of western frame construction, which is based upon the platform principle, they are seen also, at times, in balloon-framed houses.

If a solid sill is used in balloon-framed construction, the framing shown in *Plate* 1 should be modified, somewhat as illustrated in Fig. *a*, *Plate* 4.

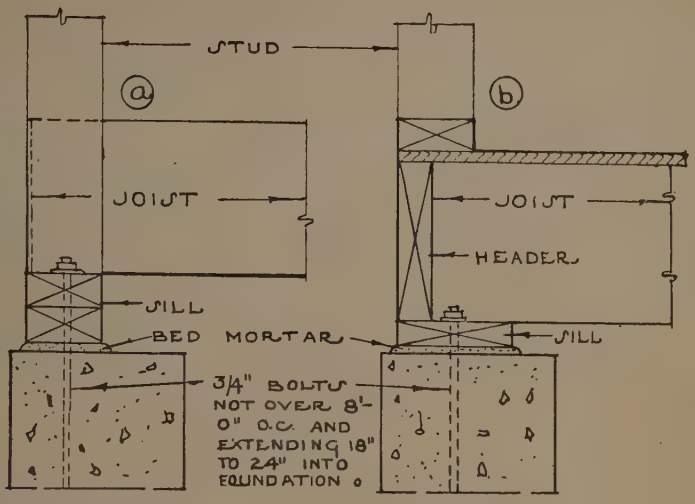
When it is desired to bring the finished grade up to the first-floor level, some provision should be made to keep the soil and moisture from contact with the joists and sills. Figure *c* shows an effective method. The masonry wall is stepped, as illustrated, to provide joist bearing and is run up almost to the top of the joists. In this particular design, a wide sill (2 by 8 in.) is used to provide a nailing surface for the subfloor.

BASEMENT POSTS

Basement posts supporting girders should be set on masonry footings. The base of the post, where it comes in contact with the masonry, may be coated with asphalt; though a better practice is to raise the masonry footing not less than 3 in. above the floor or ground level, to prevent the accumulation of water or moisture at the bottom of the posts. If this is done it may not be necessary to asphalt the bottom of the posts, though it is a wise precaution to take in any case. All timber columns or posts should be provided with adequate footings or base plates. See Chap. X for posts in heavy construction.

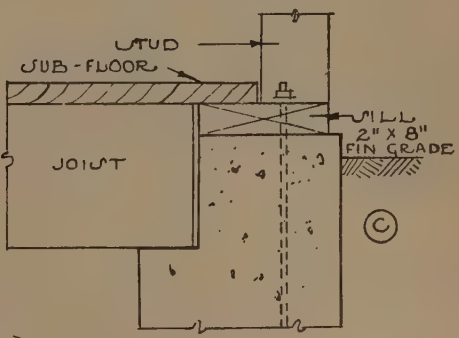
Table 4 shows the allowable safe load per square inch of cross-section area on columns or posts for various species of lumber of quality equivalent to the basic provisions for structural material of the American Lumber Standards.

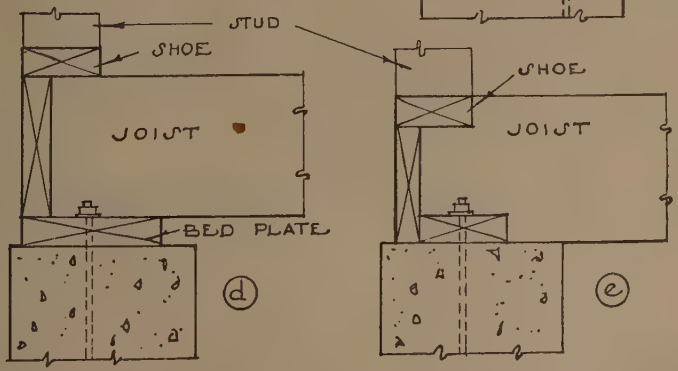
For example, assume that the total load to be carried is 6,000 lb., the post is 9 ft. long and of redwood, equivalent in quality to the American Standard common structural grade. Assume a 6-in. ($5\frac{1}{2}$ in. actual) square post. The ratio of l to d is then $9 \times 12 \div 5\frac{1}{2} = 20$ (approximately). From Table 4 under $l/d = 20$, it is found opposite redwood that a load of 688 lb. per square inch of cross-section area will be safely supported by that post. As the area of this post is $5\frac{1}{2} \times 5\frac{1}{2} = 30.25$ sq. in., its total safe load is $30.25 \times 688 = 20{,}812$ lb., which is more than three times the load to be carried. Apparently, a 4-in. post (actually $3\frac{5}{8}$ in. square), with a cross-section area of 9.7 sq. in., would be satisfactory but the l/d of this 4-in. post is $9 \times 12 \div 3\frac{5}{8} = 30$ approximately, and for that ratio, the table permits a load of only 365 lb. per square inch, thus allowing a total load of 3,540 lb. which is less than the load to



SOLID SILL BOX SILL

METHOD OF PROTECTING JOISTS BELOW GRADE.





METHODS OF FRAMING JOISTS WITH BOX SILLS.

TYPICAL · SILL · CONSTRUCTION

Plate 4.

TABLE 4.[1]—SAFE LOAD IN POUNDS PER SQUARE INCH OF CROSS-SECTIONAL AREA OF SQUARE AND RECTANGULAR TIMBER COLUMNS

(Dry locations)

Compiled from Data from Forest Products Laboratory

All timber columns, posts, and other vertical supports shall be of sufficient strength to support safely the combined live and dead loads transmitted to them.

Safe loads and allowable working stresses in compression parallel to grain for timber columns shall not exceed in pounds per square inch the values given in the following table for the respective species, grade, and ratio of unsupported length to least dimension (L/D):

Species of lumber	[2]American standard basic grade	[3]Ratio of length to least dimension (L/D)										
		10 and less, pounds	L/D 12, pounds	L/D 14, pounds	L/D 16, pounds	L/D 18, pounds	L/D 20, pounds	L/D 25, pounds	L/D 30, pounds	L/D 35, pounds	L/D 40, pounds	L/D 50, pounds
Commercial white ash	Select	1,100	1,076	1,055	1,023	978	913	658	457	336	257	164
	Common	880	868	857	840	818	784	647				
Western red cedar; Balsam fir	Select	700	686	674	656	629	592	438	304	224	171	110
	Common	560	553	547	538	524	505	425				
Northern and southern white cedar	Select	550	540	530	516	496	468	351	244	179	137	88
	Common	440	435	430	423	412	398	338				
Chestnut; Northern white, Idaho white, sugar, California white, and Pondosa pine	Select	750	733	718	695	663	617	438	304	224	171	110
	Common	600	591	583	572	556	532	434				
Southern cypress; Western larch	Select	1,100	1,063	1,030	981	909	810	526	365	268	206	132
	Common	880	861	843	818	781	729					
Douglas fir (Coast region); Southern yellow pine; Beech; yellow and sweet birch; Sugar maple	Dense[4] Select	1,285	1,251	1,222	1,176	1,112	1,022	702	487	358	274	175
	Select[5]	1,175	1,149	1,127	1,093	1,045	975	702				
	Dense Common	1,025	1,017	996	965	935	893	698				
	Common	880	870	861	847	826	796	675				
Douglas fir (Rocky Mountain region); red, white and Sitka spruce; Norway pine, Alaska cedar, Slippery and white elm; sycamore; red and black gum; tupelo	Select	800	786	774	753	726	688	526	365	268	206	132
	Common	640	632	627	617	602	582	500				
West Coast hemlock	Select	900	885	872	852	823	783	614	426	313	240	153
	Common	720	712	706	696	680	660	573				
Eastern hemlock; Commercial white fir	Select	700	689	678	664	641	611	482	335	246	188	121
	Common	560	554	549	542	530	515	449				
White and red oak	Select	1,000	982	967	943	908	860	658	457	336	257	164
	Common	800	790	783	771	753	728	625				
Redwood	Select	1,000	972	947	910	856	781	526	365	268	206	132
	Common	800	786	773	754	726	688					
Englemann spruce	Select	600	586	574	556	530	494	351	244	179	137	88
	Common	480	473	466	457	444	426	347				
Tamarack	Select	1,000	976	955	923	877	817	570	396	291	223	142
	Common	800	788	777	761	737	706	566				

[1] For explanation of use, see p. 242.

[2] Material equivalent in quality to the corresponding basic provision for structural material of American Lumber Standards.

[3] For columns with L to D intermediate between those which are given in this table, the safe load in pounds per square inch may be determined by interpolation.

No column shall be used with greater unsupported length than fifty times its least diameter.

[4] This grade applies only to Douglas fir and southern pine.

[5] This grade does not apply to southern pine.

be carried. Consequently, the 6 × 6 post must be used, although it is stronger than necessary.

JOISTS

In the section on the general principles of light framing it was shown to be poor economy to skimp on the depth of joists, because the material of greater depth, even if of a lower grade, will often give the more satisfactory floor. Stiffness in floor joists must be assured if boards are to be kept from squeaking, partitions from sagging, doors from sticking, and plaster underneath from cracking.

It is not, moreover, usually good economy to use joists over 16 ft. long, since doing so requires additional bridging, a greater depth of joist, and usually a considerable advance in the price per board foot of lumber.

Floor joists should be rigidly bridged at intervals not exceeding 8 ft., and a careful check should be made to see that the tops of the joists are level, before the flooring is laid. Equal depth can be obtained by "sizing" or cutting the necessary fraction of an inch from the bottom of the joists near the ends. It is important that this be done, for joists must have equal depth at the supports to insure a level floor. Joists are usually placed 16 in. on centers in dwellings to match the stud spacing, which, in turn, is governed by the length of the wood lath. Wood laths are manufactured in lengths which are multiples of 16 in. The most common length is 4 ft., although some 32-in. laths are produced. While the spacing of joists for convenience in framing is usually made to coincide with the spacing of the studs, joist spacing actually depends, of course, upon the loading and upon the type of building.

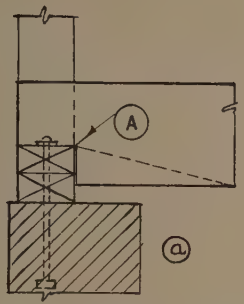
Joists resting on or entering walls of masonry or concrete should have a bearing of not less than 3 in., be anchored at suitable intervals, and be self-releasing or supported by suitable metal hangers. T-shaped steel anchors, at intervals of not more than 6 ft., attached in a way to afford easy release in case of fire burning through the joists, are recommended. Joists running parallel with masonry enclosing walls should be anchored to the walls at least once between bearings with steel anchors. Such anchors should extend through and engage at least three joists. Though this method of anchoring joists to masonry enclosing walls is not commonly used, it is good practice, especially if the building is several stories high, and is essential to safety in a region normally subjected to very high winds or earthquakes. On account of the likelihood of decay, no wood beam should ever be enclosed in masonry unless an air space for ventilation is provided, and it is recommended that the joist surfaces in contact with the masonry be asphalted. Joists carrying non-bearing

partitions running in the same direction should be doubled. If non-bearing partitions cross joists near their center, these joists should be of the size required for normal loading, with a span 2 ft. greater than the actual span. Joists around stair wells and other openings should also be doubled, and here, as in all other places, they should be placed with knots on top, as explained in Chap. I.

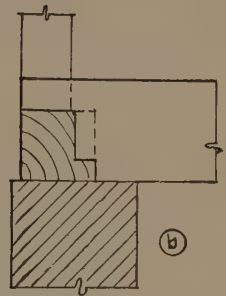
The resistance to compression across the grain may be increased considerably by having the joists supported on a ribbon board and spiked to the studding, the reason being that joists so connected are more certain of being dry and consequently resist compression better than when the ends rest upon or in masonry. Joists spiked to the studding also gain some support through the nails, and, since the stress is not at the extreme end of the joist, a slight overload will not cause it to yield so much as it would if it merely rested upon a wide support.

One of the best methods of framing joists at the sill is to support them directly on the sill and to have them spiked against the sides of the studs. The method of cutting shown in Fig. *a*, *Plate* 5, should never be tolerated, because it causes great weakness and cracking at *A*. It is interesting to note, in fact, that a joist cut along the dotted lines shown in this figure will actually carry a greater load than if it is cut square against the girder. The method of framing joists to sills, illustrated in Fig. *b*, is commonly used either with a square or a notched sill but is not desirable. When it is used the cutting must be accurate, or the top half of the joist will either carry all of the load or be left in the air without bearing.

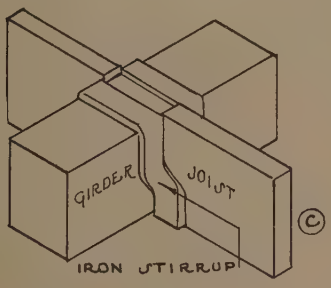
By raising the girders so that the top of the joists will be flush with the top of the girder, the head room in the basement is increased. A good method of doing this is to use iron stirrups, as shown in Fig. *c*, although many prefer a duplex hanger, as shown in Fig. 99 (Chap. X). The shrinkage possibilities of such framing should be borne in mind, as the combined shrinkage in the girder and the joist will be transmitted to the flooring, just as if the joist were resting on top of the girder. Figure *d* shows another method of accomplishing the same result, which, though somewhat inferior in strength to the method shown in Fig. *c*, is extensively used. There are two points to be observed, however, in the approved method of framing joists to girders by means of the strips shown. These points are, first, securing the strips to either side of the girder by means of through bolts, instead of simply nailing each strip separately to the girder; second, setting the joists so that their tops will be ¼ in. or more above the top of the girder. This is advisable in order to avoid the possibility of the joists' settling below the level of the girders and so causing a bulge in the flooring over the girder. If decreasing the head room under

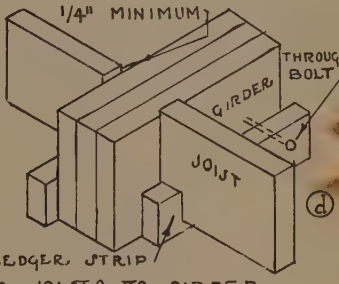


DETAIL SOMETIMES USED IN ORDER TO REDUCE THE HEIGHT OF JOIST ON SILL.

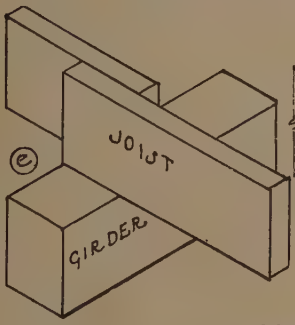


COMMON METHOD OF FRAMING JOIST TO SILL.

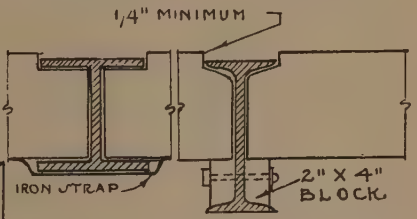




TWO METHODS OF FRAMING JOISTS TO GIRDER

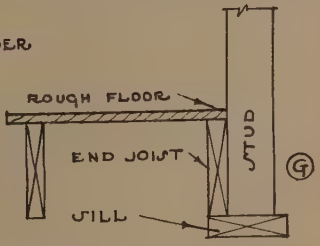


JOISTS LAPPED ON TOP OF GIRDER



(f.) JOISTS FRAMED INTO I-BEAM.

END JOIST NAILED AGAINST STUDS TO PROVIDE NAILING SURFACE FOR ENDS OF FLOOR BOARDS.



JOIST FRAMING ~ TYPICAL DETAILS

Plate 5.

the girders will not interfere with piping or other basement details, the joists may rest on top of the girders with their ends lapped and spiked together, as shown in Fig. *e*, and as indicated in the three general types of framing shown in *Plates* 1, 2 and 3. This is the best method from a structural standpoint, but it gives increased shrinkage possibilities, the same as when hangers or stirrups are used, and does not provide fire stopping where the basement ceiling is to be finished, unless headers are cut in between the joists, over the girder, to block off the air passages. If I-beams are used as girders, the joists can be framed into them in several ways. Steel stirrups may be looped over the I beam to support a joist on each side; 2 by 4-in. blocks, resting on bottom flange as shown in Fig. *f*, may be bolted through the flange and act as a support; or for light loadings, the joists may be framed to rest directly on the bottom flange. On solid sills running parallel with the joists, the end joist should be placed as shown in Fig. *g*, to provide both a fire stop between the studs and a nailing surface for the flooring.

In all of these methods, the top of the joists should be set approximately ¼ to ⅜ in. above the top of the I-beam, as shown in Fig. *f*.

Most cities now have building codes which prescribe minimum live-load requirements for various classes of buildings. There are some localities which have no codes, however, and for such, recommendations based on those of the Building Code Committee of the Department of Commerce, issued Nov. 1, 1924, are given as a general guide for three classes of structures.

	Pounds per Square Foot
Residences, hotel guest rooms, hospital wards, etc	40
Churches, schools, theatres, offices, etc	50
Aisles, lobbies, and other similar spaces in public buildings	100

For industrial or commercial buildings, the live load should be assumed as the maximum caused by the use which the building is to serve.

Tables 5 to 21, prepared by Richard G. Kimbell and published by the National Lumber Manufacturers Association, give information as to the maximum safe spans for joists under the uniform live loads and for the working stress, joist size, and spacing combinations usually encountered in buildings. All of the spans given in the tables are calculated for lumber sizes based upon American Lumber Standards. Knowing the live load in pounds per square foot which is to be supported, the spacing of the joists center to center, the size of the joists, and the species and grade of lumber used, and having ascertained the allowable working stress for that species and grade by reference either to the local building code or to tables in Chap. II, it is comparatively easy to determine the maxi-

mum safe span for the joist size under consideration, by turning to the table which gives the spans for that particular floor load. Reading across from the size of joists and spacing on centers used, the maximum allowable span will be found under the column headed by the allowable working stress.

TABLE 5.—PROPERTIES OF AMERICAN STANDARD YARD LUMBER AND TIMBER SIZES

Nominal size, inches	American Standard dressed size, inches	Area of section $A = bd$, square inches	Weight per linear foot,[1] pounds	Moment of inertia, $I = \frac{bd^3}{12}$	Section modulus, $S = \frac{bd^2}{6}$	Nominal size, inches	American Standard dressed size, inches	Area of section $A = bd$, square inches	Weight per linear foot,[1] pounds	Moment of inertia, $I = \frac{bd^3}{12}$	Section modulus, $S = \frac{bd^2}{6}$
2 × 4	1⅝ × 3⅝	5.89	1.6	6.45	3.56	10 × 20	9½ × 19½	185.25	51.4	5,870.05	602.06
2 × 6	1⅝ × 5⅝	9.14	2.5	24.10	8.57	10 × 22	9½ × 21½	204.25	56.7	7,867.81	731.89
2 × 8	1⅝ × 7½	12.19	3.4	57.13	15.32	10 × 24	9½ × 23½	223.25	62.0	10,274.06	874.39
2 × 10	1⅝ × 9½	15.44	4.3	116.09	24.44	10 × 26	9½ × 25½	242.25	67.3	13,126.81	1,029.56
2 × 12	1⅝ × 11½	18.69	5.2	205.94	35.82	10 × 28	9½ × 27½	261.25	72.5	16,465.24	1,197.39
2 × 14	1⅝ × 13½	23.62	6.5	333.15	49.36	10 × 30	9½ × 29½	280.25	77.8	20,333.79	1,377.89
2 × 16	1⅝ × 15½	25.18	7.0	504.24	65.07	12 × 12	11½ × 11½	132.25	36.7	1,457.50	253.47
2 × 18	1⅝ × 17½	28.43	7.9	725.71	82.94	12 × 14	11½ × 13½	155.25	43.1	2,357.85	349.31
2 × 20	1⅝ × 19½	31.69	8.8	1,004.05	102.98	12 × 16	11½ × 15½	178.25	49.5	3,568.70	460.48
3 × 4	2⅝ × 3⅝	9.51	2.6	10.42	5.75	12 × 18	11½ × 17½	201.25	55.9	5,136.49	586.98
3 × 6	2⅝ × 5⅝	14.76	4.2	38.93	13.84	12 × 20	11½ × 19½	224.25	62.3	7,105.90	728.81
3 × 8	2⅝ × 7½	19.68	5.7	92.28	24.60	12 × 22	11½ × 21½	247.25	68.7	9,524.24	885.98
3 × 10	2⅝ × 9½	24.93	7.2	187.55	39.48	12 × 24	11½ × 23½	270.25	75.0	12,437.08	1,058.47
3 × 12	2⅝ × 11½	30.18	8.8	332.69	57.86	12 × 26	11½ × 25½	293.25	81.4	15,890.42	1,246.31
3 × 14	2⅝ × 13½	35.43	10.3	538.21	79.73	12 × 28	11½ × 27½	316.25	87.8	19,932.58	1,449.47
3 × 16	2⅝ × 15½	40.68	11.3	814.60	105.11	12 × 30	11½ × 29½	339.25	94.2	24,602.61	1,667.97
3 × 18	2⅝ × 17½	45.94	12.8	1,172.36	133.98	14 × 14	13½ × 13½	182.25	50.6	2,767.92	410.06
3 × 20	2⅝ × 19½	51.19	14.21	1,622.00	166.36	14 × 16	13½ × 15½	209.25	58.1	4,189.36	540.56
4 × 4	3⅝ × 3⅝	13.14	3.6	14.38	7.94	14 × 18	13½ × 17½	236.25	65.6	6,029.29	689.06
4 × 6	3⅝ × 5⅝	20.39	5.7	53.76	19.11	14 × 20	13½ × 19½	263.25	73.1	8,341.73	855.56
4 × 8	3⅝ × 7½	27.18	7.5	127.44	33.98	14 × 22	13½ × 21½	290.25	80.6	11,180.67	1,040.06
4 × 10	3⅝ × 9½	34.43	9.6	258.99	54.52	14 × 24	13½ × 23½	317.25	88.1	14,600.10	1,242.56
4 × 12	3⅝ × 11½	41.68	11.6	459.42	79.90	14 × 26	13½ × 25½	344.25	95.6	18,654.04	1,463.06
4 × 14	3⅝ × 13½	48.93	13.6	743.23	110.11	14 × 28	13½ × 27½	371.25	103.1	23,398.73	1,701.56
4 × 16	3⅝ × 15½	56.18	15.6	1,124.90	145.15	14 × 30	13½ × 29½	398.25	110.6	28,881.42	1,958.06
4 × 18	3⅝ × 17½	63.43	17.6	1,618.96	185.02	16 × 16	15½ × 15½	240.25	66.7	4,809.98	620.64
4 × 20	3⅝ × 19½	70.69	19.6	2,239.88	229.73	16 × 18	15½ × 17½	271.25	75.3	6,922.49	791.14
6 × 6	5½ × 5½	30.25	8.4	76.25	27.73	16 × 20	15½ × 19½	302.25	83.9	9,577.50	982.31
6 × 8	5½ × 7½	41.25	11.4	193.35	51.56	16 × 22	15½ × 21½	333.25	92.5	12,837.00	1,194.14
6 × 10	5½ × 9½	52.25	14.5	329.96	82.73	16 × 24	15½ × 23½	364.25	101.2	16,763.00	1,426.64

6 × 12	5½ × 11½	63.25	17.5	697.06	121.23	16 × 26	15½ × 25½	395.25	109.8	21,417.50	1,679.81
6 × 14	5½ × 13½	74.25	20.6	1,127.66	167.06	16 × 28	15½ × 27½	426.25	118.4	26,863.78	1,953.64
6 × 16	5½ × 15½	85.25	23.6	1,706.76	220.22	16 × 30	15½ × 29½	457.25	127.0	33,159.98	2,248.14
6 × 18	5½ × 17½	96.25	26.7	2,456.36	280.73	18 × 18	17½ × 17½	306.25	85.0	7,815.73	893.23
6 × 20	5½ × 19½	107.25	29.8	3,398.46	348.56	18 × 20	17½ × 19½	341.25	94.8	10,813.33	1,109.06
6 × 22	5½ × 21½	118.25	32.8	4,555.05	423.73	18 × 22	17½ × 21½	376.25	104.5	14,493.43	1,348.23
8 × 8	7½ × 7½	56.25	15.6	263.67	70.31	18 × 24	17½ × 23½	411.25	114.2	18,926.02	1,610.72
8 × 10	7½ × 9½	71.25	19.8	535.85	112.81	18 × 26	17½ × 25½	446.25	123.9	24,181.11	1,896.56
8 × 12	7½ × 11½	86.25	23.9	950.55	165.31	18 × 28	17½ × 27½	481.25	133.7	30,331.62	2,205.72
8 × 14	7½ × 13½	101.25	28.0	1,537.73	227.81	18 × 30	17½ × 29½	516.25	143.4	37,438.79	2,538.22
8 × 16	7½ × 15½	116.25	32.0	2,327.42	300.31	20 × 20	19½ × 19½	380.25	105.6	12,049.49	1,235.81
8 × 18	7½ × 17½	131.25	36.4	3,349.60	382.81	20 × 22	19½ × 21½	419.25	116.4	16,149.86	1,502.31
8 × 20	7½ × 19½	146.25	40.6	4,634.30	475.31	20 × 24	19½ × 23½	458.25	127.3	21,089.04	1,794.81
8 × 22	7½ × 21½	161.25	44.8	6,211.48	577.81	20 × 26	19½ × 25½	497.25	138.1	26,944.73	2,113.31
8 × 24	7½ × 23½	176.25	48.9	8,111.17	690.31	20 × 28	19½ × 27½	536.25	148.9	33,798.17	2,457.81
10 × 10	9½ × 9½	90.25	25.0	678.75	142.89	20 × 30	19½ × 29½	575.25	159.8	41,717.61	2,828.31
10 × 12	9½ × 11½	109.25	30.3	1,204.01	209.39	24 × 24	23½ × 23½	552.25	153.4	25,414.96	2,162.97
10 × 14	9½ × 13½	128.25	35.6	1,947.78	288.56	24 × 26	23½ × 25½	599.25	166.4	32,471.80	2,546.81
10 × 16	9½ × 15½	147.25	40.9	2,948.04	380.39	24 × 28	23½ × 27½	646.25	179.5	40,731.06	2,916.97
10 × 18	9½ × 17½	166.25	46.1	4,242.80	484.89	24 × 30	23½ × 29½	693.25	192.5	50,274.98	3,408.47

[1] Based on assumed average weight of 40 lb. per cubic foot.

Average Weights of Various Materials

(These weights were used to determine dead loads in obtaining the span lengths in tables 6–21)

	Pounds per Square Foot
Finished floor	2.5
Rough floor	2.5
Sheathing	2.5
Plaster	10.0

Roofing

Group I.—Assumed as 2.5 lb. per square foot, including:

	Pounds per Square Foot
Shingles	2.5
Copper sheets	1.5
Copper tile	1.75
Three-ply ready roofing	1.00

Group II.—Assumed as 8 lb. per square foot, including:

	Pounds per Square Foot
Five-ply felt and gravel	7
Slate, $\frac{3}{16}$ in	$7\frac{1}{4}$
Roman tile (new style) 1 part	8
Spanish tile (new style) 1 part	8
Ludowici tile	8

TABLE 6.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 30 lb. per square foot with plastered ceiling. Live load 40 lb. per square foot with unplastered ceiling)

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)													
		Limited by deflection of $\frac{1}{360}$ of the span Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine span				Determined by bending Having determined by reference to the building code or the table on page 99 the allowable *extreme fiber stress in bending* in pounds per square inch for the species and grade of lumber used, refer to the column below with the corresponding value to determine maximum safe span									
		E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000	f = 900	f = 1,000	f = 1,100	f = 1,200	f = 1,300	f = 1,400	f = 1,500	f = 1,600	f = 1,700	f = 1,800
2 × 6	12	9′ 1″	9′ 9″	10′ 2″	10′ 8″	10′ 4″	10′ 11″	11′ 6″	12′ 0″	12′ 6″	13′ 0″	13′ 5″	13′ 10″	14′ 3″	14′ 8″
	16	8′ 4″	8′ 11″	9′ 3″	9′ 9″	9′ 1″	9′ 6″	10′ 0″	10′ 6″	10′ 10″	11′ 3″	11′ 8″	12′ 1″	12′ 5″	12′ 10″
	24	7′ 3″	7′ 9″	8′ 2″	8′ 6″	7′ 5″	7′ 10″	8′ 3″	8′ 7″	9′ 0″	9′ 4″	9′ 7″	10′ 0″	10′ 2″	10′ 6″
2 × 8	12	12′ 0″	12′ 10″	13′ 6″	14′ 0″	13′ 9″	14′ 6″	15′ 3″	15′ 11″	16′ 6″	17′ 2″	17′ 9″	18′ 4″	18′ 10″	19′ 5″
	16	11′ 0″	11′ 9″	12′ 4″	12′ 11″	12′ 0″	12′ 8″	13′ 4″	13′ 11″	14′ 5″	15′ 0″	15′ 6″	16′ 0″	16′ 6″	17′ 0″
	24	9′ 8″	10′ 3″	10′ 10″	11′ 4″	9′ 11″	10′ 5″	10′ 11″	11′ 5″	11′ 11″	12′ 4″	12′ 9″	13′ 3″	13′ 7″	14′ 0″
2 × 10	12	15′ 2″	16′ 1″	17′ 0″	17′ 9″	17′ 3″	18′ 3″	19′ 1″	19′ 11″	20′ 8″	21′ 6″	22′ 3″	23′ 0″	23′ 8″	24′ 4″
	16	13′ 11″	14′ 10″	15′ 6″	16′ 3″	15′ 1″	15′ 11″	16′ 8″	17′ 4″	18′ 2″	18′ 10″	19′ 6″	20′ 1″	20′ 9″	21′ 4″
	24	12′ 2″	13′ 0″	13′ 8″	14′ 4″	12′ 6″	13′ 3″	13′ 10″	14′ 5″	15′ 0″	15′ 7″	16′ 1″	16′ 7″	17′ 1″	17′ 8″
2 × 12	12	18′ 3″	19′ 5″	20′ 5″	21′ 4″	20′ 8″	21′ 10″	22′ 11″	23′ 11″	24′ 10″	25′ 9″	26′ 8″	27′ 7″	28′ 5″	29′ 3″
	16	16′ 9″	17′ 10″	18′ 8″	19′ 6″	18′ 1″	19′ 3″	20′ 1″	20′ 11″	21′ 10″	22′ 8″	23′ 5″	24′ 3″	24′ 11″	25′ 8″
	24	14′ 9″	15′ 8″	16′ 6″	17′ 3″	15′ 0″	15′ 10″	16′ 7″	17′ 5″	18′ 1″	18′ 9″	19′ 5″	20′ 0″	20′ 8″	21′ 3″
2 × 14	12	21′ 3″	22′ 7″	23′ 9″	24′ 9″	24′ 0″	25′ 3″	26′ 6″	27′ 8″	28′ 9″	29′ 10″	30′ 0″			
	16	19′ 6″	20′ 9″	21′ 9″	22′ 9″	21′ 0″	22′ 3″	23′ 4″	24′ 4″	25′ 3″	26′ 4″	27′ 3″	28′ 1″	29′ 0″	29′ 10″
	24	17′ 3″	18′ 4″	19′ 4″	20′ 2″	17′ 6″	18′ 6″	19′ 4″	20′ 3″	21′ 0″	21′ 10″	22′ 7″	23′ 4″	24′ 1″	24′ 9″
3 × 6	12	10′ 6″	11′ 2″	11′ 10″	12′ 4″	13′ 0″	13′ 8″	14′ 4″	15′ 0″	15′ 7″	16′ 2″	16′ 9″	17′ 4″	17′ 10″	18′ 4″
	16	9′ 7″	10′ 2″	10′ 10″	11′ 4″	11′ 4″	12′ 0″	12′ 6″	13′ 1″	13′ 8″	14′ 2″	14′ 8″	15′ 2″	15′ 8″	16′ 1″
	24	8′ 6″	9′ 0″	9′ 6″	10′ 0″	9′ 4″	9′ 11″	10′ 4″	10′ 10″	11′ 3″	11′ 7″	12′ 1″	12′ 6″	12′ 11″	13′ 3″
3 × 8	12	13′ 11″	14′ 10″	15′ 7″	16′ 4″	17′ 1″	17′ 11″	18′ 10″	19′ 8″	20′ 6″	21′ 3″	22′ 0″	22′ 9″	23′ 5″	24′ 2″
	16	12′ 10″	13′ 8″	14′ 4″	14′ 11″	15′ 0″	15′ 9″	16′ 7″	17′ 4″	18′ 0″	18′ 8″	19′ 4″	20′ 0″	20′ 7″	21′ 2″
	24	11′ 3″	12′ 0″	12′ 8″	13′ 2″	12′ 5″	13′ 1″	13′ 9″	14′ 4″	14′ 11″	15′ 6″	16′ 0″	16′ 7″	17′ 1″	17′ 6″
3 × 10	12	17′ 6″	18′ 7″	19′ 6″	20′ 5″	21′ 3″	22′ 5″	23′ 6″	24′ 7″	25′ 7″	26′ 7″	27′ 6″	28′ 5″	29′ 3″	30′ 0″
	16	16′ 0″	17′ 0″	17′ 11″	18′ 9″	18′ 9″	19′ 9″	20′ 9″	21′ 8″	22′ 7″	23′ 5″	24′ 3″	25′ 0″	25′ 9″	26′ 6″
	24	13′ 2″	15′ 1″	15′ 11″	16′ 8″	15′ 7″	16′ 5″	17′ 3″	18′ 0″	18′ 9″	19′ 5″	20′ 2″	20′ 10″	21′ 5″	22′ 1″
3 × 12	12	20′ 11″	22′ 3″	23′ 5″	24′ 5″	25′ 5″	26′ 9″	28′ 1″	29′ 4″	30′ 0″					
	16	19′ 4″	20′ 6″	21′ 7″	22′ 7″	22′ 5″	23′ 8″	24′ 10″	25′ 11″	27′ 0″	28′ 0″	29′ 0″	30′ 0″		
	24	17′ 1″	18′ 2″	19′ 2″	19′ 11″	18′ 9″	19′ 9″	20′ 9″	21′ 8″	22′ 6″	23′ 4″	24′ 2″	25′ 0″	25′ 9″	26′ 6″
3 × 14	12	23′ 4″	25′ 11″	27′ 3″	28′ 6″	29′ 5″	30′ 0″								
	16	22′ 6″	23′ 10″	25′ 2″	26′ 4″	26′ 1″	27′ 6″	28′ 10″	30′ 0″						
	24	20′ 0″	21′ 3″	22′ 4″	23′ 4″	21′ 8″	23′ 0″	24′ 3″	25′ 2″	26′ 3″	27′ 3″	28′ 2″	29′ 1″	30′ 0″	

NOTE.—When limited by deflection, the lengths are based on:
Maximum allowable deflection of $\frac{1}{360}$ of span length.
Modulus of elasticity as noted for E.
When determined by bending strength of the piece.
Allowable stress in extreme fiber in bending as noted for f.

Dead load { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load. { 30 lb. per square foot of floor area with ceiling plastered, or
40 lb. per square foot with ceiling unplastered.

TABLE 7.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 40 lb. per square foot with plastered ceiling. Live load 50 lb. per square foot with unplastered ceiling)

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)												
		Limited by deflection of 1/360 of the span Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine span				Determined by bending Having determined by reference to the building code or the table on page 99 the allowable *extreme fiber stress in bending* in pounds per square inch for the species and grade of lumber used, refer to the column below with the corresponding value to determine maximum safe span								
		E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000	f = 900	f = 1,000	f = 1,100	f = 1,200	f = 1,300	f = 1,400	f = 1,500	f = 1,600	f = 1,700	f = 1,800
2 × 6	12	8′ 6″	9′ 1″	9′ 6″	10′ 0″	9′ 6″	10′ 0″	10′ 5″	10′ 11″	11′ 4″	11′ 10″	12′ 2″	12′ 7″	13′ 0″	13′ 5″
	16	7′ 9″	8′ 3″	8′ 8″	9′ 1″	8′ 3″	8′ 8″	9′ 1″	9′ 6″	9′ 10″	10′ 3″	10′ 8″	11′ 0″	11′ 4″	11′ 7″
	24	6′ 10″	7′ 3″	7′ 7″	8′ 0″	6′ 9″	7′ 1″	7′ 6″	7′ 10″	8′ 1″	8′ 5″	8′ 9″	9′ 0″	9′ 3″	9′ 6″
2 × 8	12	11′ 5″	12′ 0″	12′ 8″	13′ 3″	12′ 6″	13′ 2″	13′ 10″	14′ 5″	15′ 0″	15′ 7″	16′ 1″	16′ 8″	17′ 2″	17′ 8″
	16	10′ 5″	11′ 0″	11′ 7″	12′ 1″	10′ 11″	11′ 6″	12′ 0″	12′ 7″	13′ 1″	13′ 8″	14′ 1″	14′ 6″	15′ 0″	15′ 5″
	24	9′ 2″	9′ 8″	10′ 2″	10′ 8″	8′ 11″	9′ 5″	9′ 11″	10′ 4″	10′ 9″	11′ 2″	11′ 7″	12′ 0″	12′ 4″	12′ 8″
2 × 10	12	14′ 4″	15′ 2″	16′ 0″	16′ 8″	15′ 9″	16′ 7″	17′ 4″	18′ 2″	18′ 11″	19′ 7″	20′ 3″	21′ 0″	21′ 8″	22′ 3″
	16	13′ 1″	13′ 10″	14′ 7″	15′ 3″	13′ 9″	14′ 6″	15′ 2″	15′ 10″	16′ 6″	17′ 1″	17′ 9″	18′ 4″	18′ 10″	19′ 5″
	24	11′ 6″	12′ 2″	12′ 10″	13′ 5″	11′ 4″	11′ 11″	12′ 6″	13′ 1″	13′ 8″	14′ 1″	14′ 7″	15′ 1″	15′ 7″	16′ 0″
2 × 12	12	17′ 3″	18′ 3″	19′ 3″	20′ 1″	18′ 11″	19′ 11″	20′ 11″	21′ 11″	22′ 8″	23′ 6″	24′ 5″	25′ 2″	26′ 0″	26′ 9″
	16	15′ 9″	16′ 9″	17′ 7″	18′ 5″	16′ 6″	17′ 5″	18′ 3″	19′ 1″	19′ 11″	20′ 7″	21′ 4″	22′ 0″	22′ 9″	23′ 5″
	24	13′ 10″	14′ 9″	15′ 6″	16′ 2″	13′ 8″	14′ 4″	15′ 1″	15′ 9″	16′ 5″	17′ 0″	17′ 7″	18′ 2″	18′ 9″	19′ 4″
2 × 14	12	20′ 0″	21′ 2″	22′ 6″	23′ 5″	21′ 11″	23′ 2″	24′ 3″	25′ 4″	26′ 4″	27′ 4″	28′ 4″	29′ 4″	30′ 0″	
	16	18′ 4″	19′ 6″	20′ 6″	21′ 5″	19′ 3″	20′ 3″	21′ 3″	22′ 3″	23′ 2″	24′ 0″	24. 10″	25′ 8″	26′ 6″	27′ 3″
	24	16′ 3″	17′ 3″	18′ 1″	18′ 11″	15′ 11″	16′ 9″	17′ 7″	18′ 5″	19′ 2″	19′ 10″	20′ 7″	21′ 3″	21′ 11″	22′ 6″
3 × 6	12	9′ 11″	10′ 6″	11′ 2″	11′ 8″	11′ 10″	12′ 5″	13′ 1″	13′ 8″	14′ 3″	14′ 9″	15′ 3″	15′ 9″	16′ 3″	16′ 9″
	16	9′ 1″	9′ 8″	10′ 2″	10′ 8″	10′ 4″	10′ 11″	11′ 5″	11′ 11″	12′ 5″	12′ 10″	13′ 4″	13′ 9″	14′ 3″	14′ 9″
	24	7′ 11″	8′ 5″	8′ 11″	9′ 4″	8′ 6″	8′ 11″	9′ 5″	9′ 9″	10′ 3″	10′ 8″	11′ 0″	11′ 4″	11′ 9″	12′ 0″
3 × 8	12	13′ 1″	13′ 11″	14′ 8″	15′ 4″	15′ 7″	16′ 5″	17′ 3″	18′ 0″	18′ 9″	19′ 5″	20′ 1″	20′ 9″	21′ 5″	22′ 0″
	16	12′ 0″	12′ 9″	13′ 5″	14′ 0″	13′ 8″	14′ 5″	15′ 1″	15′ 9″	16′ 5″	17′ 0″	17′ 8″	18′ 3″	18′ 9″	19′ 4″
	24	10′ 8″	11′ 3″	11′ 10″	12′ 4″	11′ 3″	11′ 10″	12′ 5″	13′ 0″	13′ 7″	14′ 1″	14′ 7″	15′ 0″	15′ 6″	15′ 11″
3 × 10	12	16′ 5″	17′ 6″	18′ 5″	19′ 3″	19′ 6″	20′ 7″	21′ 7″	22′ 6″	23′ 3″	24′ 4″	25′ 2″	26′ 0″	26′ 9″	27′ 7″
	16	15′ 1″	16′ 1″	16′ 11″	17′ 8″	17′ 2″	18′ 1″	18′ 11″	19′ 9″	20′ 8″	21′ 4″	22′ 2″	22′ 10″	23′ 7″	24′ 3″
	24	13′ 4″	14′ 2″	14′ 11″	15′ 7″	14′ 3″	15′ 0″	15′ 9″	16′ 5″	17′ 1″	17′ 9″	18′ 4″	18′ 11″	19′ 6″	20′ 1″
3 × 12	12	19′ 9″	20′ 11″	22′ 1″	23′ 1″	23′ 4″	24′ 7″	25′ 9″	26′ 11″	28′ 0″	29′ 1″	30′ 0″			
	16	18′ 2″	19′ 4″	20′ 4″	21′ 3″	20′ 6″	21′ 8″	22′ 9″	23′ 9″	24′ 8″	25′ 8″	26′ 6″	27′ 5″	28′ 3″	29′ 1″
	24	16′ 1″	17′ 1″	18′ 0″	18′ 9″	17′ 1″	18′ 0″	18′ 10″	19′ 9″	20′ 6″	21′ 4″	22′ 1″	22′ 9″	23′ 6″	24′ 2″
3 × 14	12	23′ 1″	24′ 5″	25′ 9″	26′ 11″	27′ 0″	28′ 6″	30′ 0″							
	16	21′ 3″	22′ 6″	23′ 9″	24′ 10″	23′ 11″	25′ 2″	26′ 5″	27′ 7″	28′ 9″	29′ 9″	30′ 0″			
	24	18′ 9″	20′ 0″	21′ 0″	22′ 1″	19′ 11″	21′ 0″	22′ 0″	23′ 0″	23′ 11″	24′ 10″	25′ 9″	26′ 7″	27′ 5″	28′ 2″

NOTE.—When limited by deflection, the lengths are based on:
Maximum allowable deflection of 1/360 of span length.
Modulus of elasticity as noted for E.
When determined by bending strength of the piece,
Allowable stress in extreme fiber in bending as noted for f.

Dead load { Weight of joist. Weight of lath and plaster ceiling (10 lb. per square foot). Double thickness of flooring (5 lb. per square foot).

Live load { 40 lb. per square foot of floor area with plastered ceiling, or 50 lb. per square foot with ceiling unplastered.

TABLE 8.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 50 lb. per square foot with plastered ceiling. Live load 60 lb. per square foot with unplastered ceiling)

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)												
		Limited by deflection of 1/360 of the span Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine span				Determined by bending Having determined by reference to the building code or the table on page 99 the allowable *extreme fiber stress in bending* in pounds per square inch for the species and grade of lumber used, refer to the column below with the corresponding value to determine maximum safe span								
		E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000	f = 900	f = 1,000	f = 1,100	f = 1,200	f = 1,300	f = 1,400	f = 1,500	f = 1,600	f = 1,700	f = 1,800
2 × 6	12	8′ 1″	8′ 7″	9′ 0″	9′ 6″	8′ 9″	9′ 3″	9′ 8″	10′ 0″	10′ 6″	10′ 11″	11′ 3″	11′ 7″	11′ 11″	12′ 4″
	16	7′ 4″	7′ 10″	8′ 3″	8′ 7″	7′ 8″	8′ 0″	8′ 4″	8′ 9″	9′ 1″	9′ 5″	9′ 9″	10′ 1″	10′ 5″	10′ 9″
	24	6′ 6″	6′ 10″	7′ 3″	7′ 7″	6′ 3″	6′ 7″	6′ 10″	7′ 3″	7′ 6″	7′ 10″	8′ 1″	8′ 4″	8′ 6″	8′ 10″
2 × 8	12	10′ 9″	11′ 5″	12′ 0″	12′ 7″	11′ 7″	12′ 2″	12′ 9″	13′ 4″	13′ 10″	14′ 5″	14′ 11″	15′ 5″	15′ 10″	16′ 3″
	16	9′ 9″	10′ 5″	11′ 0″	11′ 6″	10′ 1″	10′ 8″	11′ 2″	11′ 8″	12′ 2″	12′ 7″	13′ 0″	13′ 5″	13′ 10″	14′ 3″
	24	8′ 7″	9′ 2″	9′ 8″	10′ 1″	8′ 3″	8′ 9″	9′ 2″	9′ 6″	9′ 11″	10′ 4″	10′ 8″	11′ 0″	11′ 4″	11′ 8″
2 × 10	12	13′ 7″	14′ 5″	15′ 2″	15′ 10″	14′ 7″	15′ 4″	16′ 1″	16′ 10″	17′ 6″	18′ 2″	18′ 9″	19′ 5″	19′ 11″	20′ 7″
	16	12′ 5″	13′ 2″	13′ 10″	14′ 7″	12′ 8″	13′ 4″	14′ 0″	14′ 8″	15′ 3″	15′ 10″	16′ 5″	16′ 11″	17′ 6″	18′ 0″
	24	10′ 0″	11′ 7″	12′ 2″	12′ 9″	10′ 5″	11′ 0″	11′ 6″	12′ 1″	12′ 7″	13′ 1″	13′ 6″	13′ 11″	14′ 4″	14′ 9″
2 × 12	12	16′ 4″	17′ 5″	18′ 3″	19′ 1″	17′ 6″	18′ 5″	19′ 4″	20′ 2″	21′ 0″	21′ 10″	22′ 7″	23′ 4″	24′ 0″	24′ 9″
	16	14′ 11″	15′ 10″	16′ 9″	17′ 6″	15′ 3″	16′ 2″	16′ 11″	17′ 8″	18′ 5″	19′ 1″	19′ 9″	20′ 5″	21′ 0″	21′ 8″
	24	13′ 1″	14′ 0″	14′ 9″	15′ 5″	12′ 7″	13′ 4″	13′ 11″	14′ 7″	15′ 2″	15′ 9″	16′ 3″	16′ 10″	17′ 4″	17′ 10″
2 × 14	12	19′ 1″	20′ 3″	21′ 4″	22′ 4″	20′ 4″	21′ 5″	22′ 6″	23′ 6″	24′ 6″	25′ 4″	26′ 3″	27′ 1″	28′ 0″	28′ 9″
	16	17′ 6″	18′ 6″	19′ 6″	20′ 5″	17′ 10″	18′ 9″	19′ 8″	20′ 7″	21′ 5″	22′ 3″	23′ 0″	23′ 9″	24′ 6″	25′ 3″
	24	15′ 5″	16′ 4″	17′ 3″	18′ 0″	14′ 8″	15′ 6″	16′ 3″	17′ 0″	17′ 8″	18′ 4″	19′ 0″	19′ 8″	20′ 3″	20′ 10″
3 × 6	12	9′ 5″	9′ 8″	10′ 6″	11′ 0″	10′ 11″	11′ 6″	12′ 1″	12′ 7″	13′ 2″	13′ 8″	14′ 1″	14′ 7″	15′ 0″	15′ 6″
	16	8′ 7″	9′ 1″	9′ 7″	10′ 0″	9′ 6″	10′ 0″	10′ 6″	11′ 0″	11′ 6″	11′ 11″	12′ 3″	12′ 8″	13′ 1″	13′ 5″
	24	7′ 6″	8′ 0″	8′ 5″	8′ 10″	7′ 10″	8′ 3″	8′ 8″	9′ 0″	9′ 5″	9′ 10″	10′ 1″	10′ 5″	10′ 9″	11′ 1″
3 × 8	12	12′ 6″	13′ 3″	14′ 0″	14′ 7″	14′ 5″	15′ 2″	16′ 0″	16′ 8″	17′ 4″	18′ 0″	18′ 8″	19′ 3″	19′ 10″	20′ 5″
	16	11′ 5″	12′ 1″	12′ 9″	13′ 4″	12′ 7″	13′ 4″	14′ 0″	14′ 6″	13′ 2″	15′ 9″	16′ 4″	16′ 10″	17′ 4″	17′ 10″
	24	10′ 1″	10′ 8″	11′ 3″	11′ 9″	10′ 5″	11′ 0″	11′ 6″	12′ 0″	12′ 6″	13′ 0″	13′ 6″	13′ 11″	14′ 4″	14′ 9″
3 × 10	12	15′ 9″	16′ 8″	17′ 7″	18′ 4″	18′ 1″	19′ 1″	20′ 0″	20′ 11″	21′ 9″	22′ 7″	23′ 4″	24′ 2″	24′ 9″	25′ 7″
	16	14′ 5″	15′ 3″	16′ 1″	16′ 10″	15′ 11″	16′ 9″	17′ 6″	18′ 4″	19′ 1″	19′ 10″	20′ 6″	21′ 2″	21′ 10″	22′ 5″
	24	12′ 8″	13′ 5″	14′ 2″	14′ 10″	13′ 1″	13′ 10″	14′ 6″	15′ 2″	15′ 9″	16′ 4″	16′ 11″	17′ 6″	18′ 1″	18′ 7″
3 × 12	12	18′ 10″	20′ 0″	21′ 1″	22′ 0″	21′ 8″	22′ 10″	24′ 0″	25′ 0″	26′ 0″	27′ 0″	28′ 0″	29′ 0″	29′ 10″	30′ 0″
	16	17′ 4″	18′ 4″	19′ 4″	20′ 3″	19′ 0″	20′ 1″	21′ 1″	22′ 0″	22′ 11″	23′ 10″	24′ 8″	25′ 5″	26′ 2″	27′ 0″
	24	15′ 3″	16′ 3″	17′ 1″	17′ 10″	15′ 10″	16′ 8″	17′ 6″	18′ 3″	19′ 0″	19′ 9″	20′ 5″	21′ 1″	21′ 9″	22′ 4″
3 × 14	12	21′ 11″	23′ 5″	24′ 7″	25′ 8″	25′ 2″	26′ 7″	27′ 10″	29′ 1″	30′ 0″					
	16	20′ 2″	21′ 5″	22′ 7″	23′ 8″	22′ 2″	23′ 5″	24′ 6″	25′ 8″	26′ 9″	27′ 8″	28′ 8″	29′ 8″	30′ 0″	
	24	17′ 10″	18′ 11″	20′ 0″	20′ 10″	18′ 5″	19′ 5″	20′ 5″	21′ 4″	22′ 2″	23′ 0″	23′ 10″	24′ 8″	25′ 4″	26′ 1″

NOTE.—When limited by deflection, the lengths are based on:
Maximum allowable deflection of 1/360 of span length.
Modulus of elasticity as noted for E.
When determined by bending strength of the piece,
Allowable stress in extreme fiber in bending as noted for f.

Dead load { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load. { 50 lb. per square foot of floor area with plastered ceiling, or
60 lb. per square foot with ceiling unplastered.

TABLE 9.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 60 lb. per square foot with plastered ceiling. Live load 70 lb. per square foot with unplastered ceiling)

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)												
		Limited by deflection of $\frac{1}{360}$ of the span Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine span				Determined by bending Having determined by reference to the building code or the table on page 99 the allowable *extreme fiber stress in bending* in pounds per square inch for the species and grade of lumber used, refer to the column below with the corresponding value to determine maximum safe span								
		E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000	f = 900	f = 1,000	f = 1,100	f = 1,200	f = 1,300	f = 1,400	f = 1,500	f = 1,600	f = 1,700	f = 1,800
2 × 6	12	7′ 9″	8′ 2″	8′ 8″	9′ 0″	8′ 1″	8′ 6″	9′ 0″	9′ 5″	9′ 9″	10′ 2″	10′ 6″	10′ 10″	11′ 2″	11′ 6″
	16	7′ 0″	7′ 6″	7′ 11″	8′ 3″	7′ 1″	7′ 5″	7′ 10″	8′ 1″	8′ 6″	8′ 10″	9′ 1″	9′ 5″	9′ 9″	10′ 0″
	24	6′ 2″	6′ 6″	6′ 11″	7′ 2″	5′ 9″	6′ 1″	6′ 5″	6′ 8″	6′ 11″	7′ 2″	7′ 6″	7′ 8″	7′ 11″	8′ 2″
2 × 8	12	10′ 2″	10′ 11″	11′ 6″	12′ 0″	10′ 9″	11′ 4″	11′ 11″	12′ 5″	13′ 0″	13′ 6″	13′ 11″	14′ 5″	14′ 10″	15′ 3″
	16	9′ 4″	9′ 11″	10′ 6″	11′ 0″	9′ 5″	9′ 11″	10′ 4″	10′ 10″	11′ 3″	11′ 8″	12′ 1″	12′ 6″	12′ 11″	13′ 3″
	24	8′ 2″	8′ 9″	9′ 2″	9′ 7″	7′ 8″	8′ 1″	8′ 6″	8′ 11″	9′ 3″	9′ 7″	9′ 11″	10′ 3″	10′ 6″	10′ 11″
2 × 10	12	13′ 0″	13′ 9″	14′ 6″	15′ 2″	13′ 7″	14′ 4″	15′ 0″	15′ 8″	16′ 4″	16′ 11″	17′ 6″	18′ 1″	18′ 8″	19′ 2″
	16	11′ 10″	12′ 7″	13′ 3″	13′ 10″	11′ 10″	12′ 6″	13′ 1″	13′ 8″	14′ 3″	14′ 9″	15′ 3″	15′ 9″	16′ 3″	16′ 9″
	24	10′ 5″	11′ 0″	11′ 8″	12′ 1″	9′ 9″	10′ 3″	10′ 9″	11′ 3″	11′ 9″	12′ 2″	12′ 7″	13′ 0″	13′ 4″	13′ 9″
2 × 12	12	15′ 8″	16′ 8″	17′ 6″	18′ 3″	16′ 4″	17′ 3″	18′ 1″	18′ 11″	19′ 8″	20′ 5″	21′ 1″	21′ 10″	22′ 6″	23′ 2″
	16	14′ 4″	15′ 2″	16′ 0″	16′ 8″	14′ 3″	15′ 1″	15′ 9″	16′ 6″	17′ 2″	17′ 9″	18′ 5″	19′ 0″	19′ 8″	20′ 2″
	24	12′ 6″	13′ 4″	14′ 0″	14′ 8″	11′ 9″	12′ 4″	13′ 0″	13′ 7″	14′ 2″	14′ 8″	15′ 2″	15′ 8″	16′ 2″	16′ 7″
2 × 14	12	18′ 3″	19′ 5″	20′ 5″	21′ 4″	19′ 1″	20′ 1″	21′ 1″	22′ 0″	22′ 11″	23′ 10″	24′ 7″	25′ 5″	26′ 3″	26′ 11″
	16	16′ 7″	17′ 9″	18′ 7″	19′ 6″	16′ 7″	17′ 6″	18′ 5″	19′ 3″	20′ 0″	20′ 10″	21′ 6″	22′ 3″	22′ 11″	23′ 7″
	24	14′ 9″	15′ 7″	16′ 5″	17′ 3″	13′ 9″	14′ 6″	15′ 3″	15′ 11″	16′ 6″	17′ 1″	17′ 9″	18′ 4″	18′ 11″	19′ 5″
3 × 6	12	9′ 0″	9′ 7″	10′ 1″	10′ 6″	10′ 3″	10′ 10″	11′ 4″	11′ 10″	12′ 4″	12′ 10″	13′ 3″	13′ 7″	14′ 0″	14′ 6″
	16	8′ 3″	8′ 9″	9′ 3″	9′ 7″	8′ 11″	9′ 5″	9′ 10″	10′ 4″	10′ 9″	11′ 1″	11′ 6″	11′ 11″	12′ 3′	12′ 7″
	24	7′ 3″	7′ 7″	8′ 1″	8′ 5″	7′ 4″	7′ 9″	8′ 1″	8′ 5″	8′ 10″	9′ 1″	9′ 5″	9′ 9″	10′ 0″	10′ 4″
3 × 8	12	11′ 11″	12′ 9″	13′ 4″	14′ 0″	13′ 6″	14′ 3″	14′ 11″	15′ 7″	16′ 3″	16′ 11″	17′ 5″	18′ 0″	18′ 7″	19′ 1″
	16	10′ 11″	11′ 7″	12′ 3″	12′ 10″	11′ 10″	12′ 5″	13′ 0″	13′ 7″	14′ 3″	14′ 9″	15′ 3″	15′ 9″	16′ 3″	16′ 9″
	24	9′ 7″	10′ 1″	10′ 9″	11′ 3″	9′ 9″	10′ 3″	10′ 9″	11′ 3″	11′ 9″	12′ 1″	12′ 6″	13′ 0″	13′ 4″	13′ 9″
3 × 10	12	15′ 0″	15′ 11″	16′ 10″	17′ 7″	17′ 0″	17′ 11″	18′ 10″	19′ 7″	20′ 5″	21′ 3″	21′ 11″	22′ 7″	23′ 4″	24′ 0″
	16	13′ 9″	14′ 7″	15′ 5″	16′ 1″	14′ 10″	15′ 9″	16′ 5″	17′ 1″	17′ 11″	18′ 6″	19′ 3″	19′ 10″	20′ 5″	21′ 0″
	24	12′ 1″	12′ 11″	13′ 6″	14′ 1″	12′ 3″	12′ 11″	13′ 7″	14′ 1″	14′ 9″	15′ 4″	15′ 10″	16′ 4″	16′ 11″	17′ 4″

3 × 12	12	18′ 0″	19′ 3″	20′ 3″	21′ 1″	20′ 4″	21′ 5″	22′ 6″	23′ 6″	24′ 6″	25′ 5″	26′ 4″	27′ 1″	28′ 0″	28′ 10″
	16	16′ 7″	17′ 7″	18′ 6″	19′ 4″	17′ 11″	18′ 10″	19′ 9″	20′ 7″	21′ 5″	22′ 4″	23′ 0″	23′ 10″	24′ 6″	25′ 4″
	24	14′ 7″	15′ 6″	16′ 4″	17′ 0″	14′ 10″	15′ 7″	16′ 4″	17′ 1″	17′ 9″	18′ 5″	19′ 1″	19′ 9″	20′ 4″	20′ 11″
3 × 14	12	21′ 1″	22′ 5″	23′ 7″	24′ 7″	23′ 9″	25′ 0″	26′ 3″	27′ 4″	28′ 6″	29′ 6″	30′ 0″			
	16	19′ 5″	20′ 6″	21′ 7″	22′ 7″	20′ 10″	21′ 11″	23′ 0″	24′ 0″	25′ 0″	26′ 0″	26′ 11″	27′ 10″	28′ 7″	29′ 5″
	24	17′ 0″	18′ 1″	19′ 1″	20′ 0″	17′ 4″	18′ 5″	19′ 1″	19′ 11″	20′ 10″	21′ 6″	22′ 4″	23′ 0″	23′ 9″	24′ 5″
4 × 6	12	9′ 11″	10′ 7″	11′ 1″	11′ 7″	11′ 11″	12′ 6″	13′ 3″	13′ 9″	14′ 4″	14′ 11″	15′ 5″	15′ 11″	16′ 5″	16′ 11″
	16	9′ 1″	9′ 9″	10′ 3″	10′ 9″	10′ 5″	11′ 0″	11′ 6″	12′ 0″	12′ 6″	13′ 0″	13′ 6″	13′ 11″	14′ 4″	14′ 9″
	24	8′ 0″	8′ 6″	9′ 0″	9′ 4″	8′ 6″	9′ 0″	9′ 6″	9′ 11″	10′ 4″	10′ 9″	11′ 0″	11′ 5″	11′ 10″	12′ 1″
4 × 8	12	13′ 3″	14′ 0″	14′ 10″	15′ 5″	15′ 9″	16′ 7″	17′ 5″	18′ 1″	18′ 11″	19′ 7″	20′ 4″	21′ 0″	21′ 7″	22′ 3″
	16	12′ 1″	12′ 11″	13′ 6″	14′ 1″	13′ 9″	14′ 6″	15′ 3″	15′ 11″	16′ 6″	17′ 1″	17′ 9″	18′ 5″	18′ 11″	19′ 6″
	24	10′ 7″	11′ 4″	11′ 10″	12′ 5″	11′ 5″	12′ 0″	12′ 7″	13′ 1″	13′ 7″	14′ 3″	14′ 9″	15′ 3″	15′ 7″	16′ 1″
4 × 10	12	16′ 7″	17′ 7″	18′ 6″	19′ 5″	19′ 7″	20′ 9″	21′ 9″	22′ 9″	23′ 7″	24′ 6″	25′ 5″	26′ 3″	27′ 0″	27′ 10″
	16	15′ 3″	16′ 1″	17′ 0″	17′ 10″	17′ 4″	18′ 3″	19′ 1″	19′ 11″	20′ 9″	21′ 6″	22′ 4″	23′ 0″	23′ 9″	24′ 5″
	24	13′ 5″	14′ 3″	15′ 0″	15′ 9″	14′ 4″	15′ 1″	15′ 10″	16′ 6″	17′ 3″	17′ 10″	18′ 6″	19′ 1″	19′ 9″	20′ 3″

NOTE.—When limited by deflection, the lengths are based on:
Maximum allowable deflection of $\frac{1}{360}$ of span length.
Modulus of elasticity as noted for *E*.
When determined by bending strength of the piece,
Allowable stress in extreme fiber in bending as noted for *f*.

Dead load:
- Weight of joist.
- Weight of lath and plaster ceiling (10 lb. per square foot).
- Double thickness of flooring (5 lb. per square foot).

Live load:
- 60 lb. per square foot of floor area with plastered ceiling, or
- 70 lb. per square foot with ceiling unplastered.

TABLE 10.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 70 lb. per square foot with plastered ceiling. Live load 80 lb. per square foot with unplastered ceiling)

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)													
		Limited by deflection of $\frac{1}{360}$ of the span Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine span				Determined by bending Having determined by reference to the building code or the table on page 99 the allowable *extreme fiber stress in bending* in pounds per square inch for the species and grade of lumber used, refer to the column below with the corresponding value to determine maximum safe span									
		E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000	f = 900	f = 1,000	f = 1,100	f = 1,200	f = 1,300	f = 1,400	f = 1,500	f = 1,600	f = 1,700	f = 1,800
2 × 6	12	7′ 5″	7′ 9″	8′ 2″	8′ 7″	7′ 8″	8′ 1″	8′ 6″	8′ 9″	9′ 2″	9′ 6″	9′ 10″	10′ 2″	10′ 6″	10′ 9″
	16	6′ 8″	7′ 1″	7′ 6″	7′ 10″	6′ 8″	7′ 0″	7′ 5″	7′ 8″	8′ 0″	8′ 4″	8′ 7″	8′ 10″	9′ 2″	9′ 5″
	24	5′ 10″	6′ 2″	6′ 7″	6′ 10″	5′ 6″	5′ 9″	6′ 0″	6′ 5″	6′ 7″	6′ 10″	7′ 1″	7′ 4″	7′ 6″	7′ 9″
2 × 8	12	9′ 9″	10′ 5″	11′ 0″	11′ 6″	10′ 1″	10′ 8″	11′ 2″	11′ 8″	12′ 2″	12′ 7″	13′ 2″	13′ 7″	13′ 10″	14′ 5″
	16	8′ 10″	9′ 6″	10′ 0″	10′ 6″	8′ 9″	9′ 4″	9′ 9″	10′ 2″	10′ 7″	11′ 0″	11′ 5″	11′ 9″	12′ 2″	12′ 6″
	24	7′ 9″	8′ 4″	8′ 9″	9′ 2″	7′ 4″	7′ 8″	8′ 0″	8′ 5″	8′ 8″	9′ 1″	9′ 5″	9′ 8″	10′ 0″	10′ 2″
2 × 10	12	12′ 5″	13′ 1″	13′ 10″	14′ 6″	12′ 9″	13′ 6″	14′ 2″	14′ 9″	15′ 5″	16′ 0″	16′ 6″	17′ 1″	17′ 7″	18′ 1″
	16	11′ 4″	12′ 0″	12′ 8″	13′ 2″	11′ 2″	11′ 9″	12′ 4″	12′ 10″	13′ 5″	13′ 10″	14′ 5″	14′ 10″	15′ 4″	15′ 9″
	24	9′ 10″	10′ 6″	11′ 1″	11′ 7″	9′ 2″	9′ 7″	10′ 1″	10′ 7″	11′ 0″	11′ 5″	11′ 9″	12′ 2″	12′ 7″	12′ 10″
2 × 12	12	15′ 0″	15′ 10″	16′ 8″	17′ 6″	15′ 5″	16′ 4″	17′ 0″	17′ 9″	18′ 6″	19′ 2″	19′ 10″	20′ 7″	21′ 2″	21′ 9″
	16	13′ 8″	14′ 6″	15′ 4″	16′ 0″	13′ 5″	14′ 2″	14′ 10″	15′ 6″	16′ 2″	16′ 8″	17′ 5″	17′ 10″	18′ 6″	19′ 0″
	24	12′ 0″	12′ 8″	13′ 5″	14′ 0″	11′ 1″	11′ 8″	12′ 2″	12′ 9″	13′ 4″	13′ 9″	14′ 4″	14′ 9″	15′ 2″	15′ 7″
2 × 14	12	17′ 6″	18′ 7″	19′ 7″	20′ 6″	18′ 0″	19′ 0″	19′ 11″	20′ 10″	21′ 7″	22′ 5″	23′ 3″	24′ 0″	24′ 9″	25′ 5″
	16	16′ 1″	17′ 0″	17′ 11″	18′ 10″	15′ 9″	16′ 7″	17′ 5″	18′ 3″	18′ 11″	19′ 7″	20′ 4″	21′ 0″	21′ 7″	22′ 4″
	24	14′ 1″	15′ 0″	15′ 10″	16′ 6″	13′ 0″	13′ 7″	14′ 4″	15′ 0″	15′ 7″	16′ 3″	16′ 9″	17′ 4″	17′ 10″	18′ 4″
3 × 6	12	8′ 7″	9′ 3″	9′ 9″	10′ 1″	9′ 7″	10′ 1″	10′ 9″	11′ 1″	11′ 7″	12′ 0″	12′ 5″	12′ 11″	13′ 4″	13′ 7″
	16	7′ 11″	8′ 5″	8′ 10″	9′ 3″	8′ 5″	8′ 11″	9′ 4″	9′ 9″	10′ 1″	10′ 6″	10′ 11″	11′ 3″	11′ 7″	11′ 11″
	24	6′ 11″	7′ 5″	7′ 9″	8′ 1″	6′ 11″	7′ 4″	7′ 7″	8′ 0″	8′ 4″	8′ 7″	8′ 11″	9′ 3″	9′ 6″	9′ 9″
3 × 8	12	11′ 6″	12′ 3″	12′ 10″	13′ 5″	12′ 10″	13′ 6″	14′ 1″	14′ 9″	15′ 5″	15′ 11″	16′ 6″	17′ 0″	17′ 6″	18′ 0″
	16	10′ 6″	11′ 1″	11′ 9″	12′ 3″	11′ 1″	11′ 9″	12′ 4″	12′ 10″	13′ 6″	13′ 11″	14′ 5″	14′ 10″	15′ 4″	15′ 9″
	24	9′ 3″	9′ 10″	10′ 4″	10′ 10″	9′ 3″	9′ 7″	10′ 1″	10′ 7″	11′ 1″	11′ 5″	11′ 10″	12′ 3″	12′ 7″	13′ 0″
3 × 10	12	14′ 6″	15′ 5″	16′ 3″	16′ 11″	16′ 0″	16′ 11″	17′ 9″	18′ 6″	19′ 4″	20′ 0″	20′ 9″	21′ 5″	22′ 0″	22′ 9″
	16	13′ 3″	14′ 0″	14′ 10″	15′ 5″	14′ 0″	14′ 10″	15′ 6″	16′ 3″	16′ 11″	17′ 6″	18′ 1″	18′ 9″	19′ 4″	19′ 10″
	24	11′ 7″	12′ 4″	13′ 0″	13′ 7″	11′ 7″	12′ 3″	12′ 10″	13′ 4″	13′ 11″	14′ 5″	14′ 11″	15′ 5″	15′ 11″	16′ 4″

3 × 12	12	17′ 5″	18′ 6″	19′ 5″	20′ 5″	19′ 3″	20′ 3″	21′ 4″	22′ 3″	23′ 1″	24′ 0″	24′ 10″	25′ 8″	26′ 6″	27′ 4″	28′ 2″
	16	15′ 11″	16′ 11″	17′ 10″	18′ 7″	16′ 11″	17′ 10″	18′ 9″	19′ 6″	20′ 4″	21′ 0″	21′ 10″	22′ 6″	23′ 3″	23′ 11″	24′ 8″
	24	14′ 0″	14′ 11″	15′ 9″	16′ 5″	13′ 11″	14′ 9″	15′ 5″	16′ 1″	16′ 9″	17′ 5″	18′ 0″	18′ 7″	19′ 3″	19′ 9″	20′ 4″
3 × 14	12	20′ 4″	21′ 7″	22′ 7″	23′ 9″	22′ 5″	23′ 7″	24′ 10″	25′ 11″	26′ 11″	27′ 11″	28′ 11″	29′ 11″	30′ 0″		
	16	18′ 7″	19′ 10″	20′ 11″	21′ 10″	19′ 9″	20′ 9″	21′ 9″	22′ 9″	23′ 7″	24′ 6″	25′ 5″	26′ 3″	27′ 0″	27′ 10″	28′ 7″
	24	16′ 5″	17′ 6″	18′ 5″	19′ 3″	16′ 4″	17′ 3″	18′ 0″	18′ 10″	19′ 7″	20′ 4″	21′ 0″	21′ 9″	22′ 5″	23′ 0″	23′ 7″
4 × 6	12	9′ 7″	10′ 3″	10′ 9″	11′ 3″	11′ 3″	11′ 11″	12′ 5″	13′ 0″	13′ 6″	14′ 0″	14′ 6″	15′ 0″	15′ 6″	15′ 11″	16′ 4″
	16	8′ 9″	9′ 4″	9′ 10″	10′ 3″	9′ 10″	10′ 4″	10′ 11″	11′ 4″	11′ 0″	12′ 3″	12′ 9″	13′ 1″	13′ 6″	13′ 11″	14′ 4″
	24	7′ 9″	8′ 1″	8′ 7″	9′ 0″	8′ 1″	8′ 6″	8′ 11″	9′ 4″	9′ 9″	10′ 1″	10′ 5″	10′ 10″	11′ 1″	11′ 5″	11′ 9″
4 × 8	12	12′ 9″	13′ 6″	14′ 3″	14′ 10″	14′ 10″	15′ 9″	16′ 5″	17′ 1″	17′ 10″	18′ 6″	19′ 3″	19′ 10″	20′ 5″	21′ 0″	21′ 7″
	16	11′ 7″	12′ 4″	13′ 0″	13′ 7″	13′ 0″	13′ 9″	14′ 5″	15′ 0″	15′ 7″	16′ 3″	16′ 10″	17′ 4″	17′ 11″	18′ 5″	18′ 11″
	24	10′ 3″	10′ 10″	11′ 5″	12′ 0″	10′ 9″	11′ 4″	11′ 10″	12′ 5″	12′ 11″	13′ 5″	13′ 10″	14′ 4″	14′ 9″	15′ 3″	15′ 8″
4 × 10	12	15′ 11″	16′ 11″	17′ 10″	18′ 7″	18′ 7″	19′ 7″	20′ 7″	21′ 6″	22′ 4″	23′ 3″	24′ 0″	24′ 10″	25′ 7″	26′ 4″	27′ 1″
	16	14′ 7″	15′ 6″	16′ 5″	17′ 1″	16′ 4″	17′ 3″	18′ 1″	18′ 11″	19′ 7″	20′ 5″	21′ 1″	21′ 10″	22′ 5″	23′ 1″	23′ 8″
	24	12′ 11″	13′ 9″	14′ 5″	15′ 1″	13′ 6″	14′ 3″	14′ 11″	15′ 7″	16′ 3″	16′ 10″	17′ 5″	18′ 0″	18′ 6″	19′ 1″	19′ 7″

NOTE.—When limited by deflection, the lengths are based on:
Maximum allowable deflection of $\frac{1}{360}$ of span length
Modulus of elasticity as noted for *E*.
When determined by bending strength of the piece,
Allowable stress in extreme fiber in bending as noted for *f*.

Dead load { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load. { 70 lb. per square foot of floor area with plastered ceiling, or
80 lb. per square foot with ceiling unplastered.

TABLE 11.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 80 lb. per square foot with plastered ceiling. Live load 90 lb. per square foot with unplastered ceiling)

These Spans Must Be Compared and Checked with Those in Table 12

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)												
		Limited by deflection of $\frac{1}{360}$ of the span Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine span				Spans determined by bending (read carefully) Having determined by reference to the building code or the table on page 99 the allowable *extreme fiber stress in bending* in pounds per square inch for the species and grade of timber used, refer to the column below with the corresponding value to determine the span limited by the *bending strength* of the joist. Then refer to the table on page 262 and in the same manner determine the span of the joist limited by *horizontal shear* and *use the shorter of the two spans*								
		$E =$ 1,000,000	$E =$ 1,200,000	$E =$ 1,400,000	$E =$ 1,600,000	$f =$ 900	$f =$ 1,000	$f =$ 1,100	$f =$ 1,200	$f =$ 1,300	$f =$ 1,400	$f =$ 1,500	$f =$ 1,600	$f =$ 1,700	$f =$ 1,800
2 × 6	12	7′ 1″	7′ 7″	8′ 0″	8′ 4″	7′ 2″	7′ 7″	8′ 0″	8′ 4″	8′ 8″	9′ 0″	9′ 4″	9′ 8″	10′ 0″	10′ 2″
	16	6′ 6″	6′ 10″	7′ 2″	7′ 7″	6′ 4″	6′ 7″	6′ 10″	7′ 2″	7′ 6″	7′ 9″	8′ 1″	8′ 5″	8′ 7″	8′ 9″
2 × 8	12	9′ 6″	10′ 1″	10′ 7″	11′ 1″	9′ 7″	10′ 1″	10′ 7″	11′ 1″	11′ 6″	12′ 0″	12′ 5″	12′ 9″	13′ 2″	13′ 7″
	16	8′ 7″	9′ 3″	9′ 7″	10′ 1″	8′ 4″	8′ 9″	9′ 2″	9′ 8″	10′ 1″	10′ 5″	10′ 9″	11′ 1″	11′ 6″	11′ 9″
	24	7′ 6″	8′ 0″	8′ 5″	8′ 9″	6′ 9″	7′ 2″	7′ 7″	7′ 10″	8′ 2″	8′ 6″	8′ 9″	9′ 1″	9′ 5″	9′ 8″
2 × 10	12	12′ 0″	12′ 8″	13′ 5″	14′ 0″	12′ 1″	12′ 9″	13′ 5″	14′ 0″	14′ 7″	15′ 1″	15′ 7″	16′ 2″	16′ 8″	17′ 1″
	16	10′ 10″	11′ 7″	12′ 2″	12′ 9″	10′ 6″	11′ 1″	11′ 8″	12′ 2″	12′ 8″	13′ 2″	13′ 7″	14′ 1″	14′ 6″	14′ 10″
	24	9′ 7″	10′ 2″	10′ 8″	11′ 2″	8′ 7″	9′ 1″	9′ 6″	10′ 0″	10′ 5″	10′ 9″	11′ 2″	11′ 6″	11′ 10″	12′ 2″
2 × 12	12	14′ 5″	15′ 5″	16′ 2″	16′ 10″	14′ 7″	15′ 5″	16′ 1″	16′ 10″	17′ 7″	18′ 2″	18′ 10″	19′ 6″	20′ 1″	20′ 8″
	16	13′ 2″	14′ 0″	14′ 9″	15′ 5″	12′ 8″	13′ 5″	14′ 1″	14′ 8″	15′ 4″	15′ 10″	16′ 5″	17′ 0″	17′ 6″	18′ 0″
	24	11′ 7″	12′ 4″	12′ 10″	13′ 6″	10′ 5″	11′ 0″	11′ 7″	12′ 1″	12′ 7″	13′ 1″	13′ 6″	14′ 0″	14′ 5″	14′ 9″
2 × 14	12	16′ 11″	18′ 0″	19′ 0″	19′ 10″	17′ 1″	18′ 0″	18′ 11″	19′ 9″	20′ 6″	21′ 4″	22′ 0″	22′ 10″	23′ 6″	24′ 3″
	16	15′ 5″	16′ 5″	17′ 4″	18′ 1″	14′ 11″	15′ 9″	16′ 6″	17′ 3″	17′ 11″	18′ 7″	19′ 3″	19′ 10″	20′ 6″	21′ 1″
	24	13′ 7″	14′ 5″	15′ 3″	15′ 11″	12′ 4″	12′ 11″	13′ 7″	14′ 1″	14′ 10″	15′ 4″	15′ 10″	16′ 5″	16′ 11″	17′ 4″
3 × 6	12	8′ 4″	8′ 11″	9′ 4″	9′ 9″	9′ 1″	9′ 7″	10′ 1″	10′ 7″	11′ 0″	11′ 5″	11′ 10″	12′ 3″	12′ 7″	12′ 11″
	16	7′ 7″	8′ 1″	8′ 6″	8′ 11″	7′ 11″	8′ 5″	8′ 10″	9′ 3″	9′ 7″	9′ 11″	10′ 4″	10′ 7″	11′ 0″	11′ 4″
	24	6′ 9″	7′ 1″	7′ 6″	7′ 10″	6′ 7″	6′ 11″	7′ 3″	7′ 6″	7′ 11″	8′ 3″	8′ 5″	8′ 9″	9′ 0″	9′ 4″
3 × 8	12	11′ 1″	11′ 10″	12′ 5″	12′ 11″	12′ 1″	12′ 10″	13′ 5″	14′ 0″	14′ 9″	15′ 1″	15′ 7″	16′ 3″	16′ 7″	17′ 1″
	16	10′ 1″	10′ 10″	11′ 4″	11′ 10″	10′ 7″	11′ 1″	11′ 9″	12′ 3″	12′ 10″	13′ 3″	13′ 7″	14′ 1″	14′ 6″	14′ 11″
	24	8′ 11″	9′ 5″	9′ 11″	10′ 5″	8′ 9″	9′ 3″	9′ 7″	10′ 0″	10′ 6″	10′ 10″	11′ 3″	11′ 7″	11′ 11″	12′ 4″
3 × 10	12	14′ 0″	14′ 10″	15′ 7″	16′ 4″	15′ 3″	16′ 1″	16′ 10″	17′ 7″	18′ 4″	19′ 0″	19′ 7″	20′ 4″	20′ 11″	21′ 6″
	16	12′ 10″	13′ 6″	14′ 4″	14′ 11″	13′ 4″	14′ 0″	14′ 9″	15′ 5″	16′ 0″	16′ 7″	17′ 3″	17′ 9″	18′ 4″	18′ 10″
	24	11′ 3″	11′ 11″	12′ 6″	13′ 1″	11′ 0″	11′ 6″	12′ 1″	12′ 7″	13′ 3″	13′ 9″	14′ 1″	14′ 7″	15′ 1″	15′ 6″

3 × 12	12	16′ 10″	17′ 10″	18′ 10″	19′ 9″	18′ 4″	19′ 4″	20′ 3″	21′ 1″	22′ 0″	22′ 10″	23′ 7″	24′ 5″	25′ 1″	25′ 11″
	16	15′ 5″	16′ 4″	17′ 3″	18′ 0″	16′ 0″	16′ 11″	17′ 9″	18′ 6″	19′ 3″	20′ 0″	20′ 9″	21′ 5″	22′ 0″	22′ 7″
	24	13′ 6″	14′ 5″	15′ 1″	15′ 10″	13′ 3″	13′ 11″	14′ 7″	15′ 4″	15′ 11″	16′ 6″	17′ 1″	17′ 7″	18′ 3″	18′ 9″
3 × 14	12	19′ 7″	20′ 10″	21′ 11″	23′ 0″	21′ 4″	22′ 6″	23′ 7″	24′ 7″	25′ 7″	26′ 7″	27′ 6″	28′ 5″	29′ 4″	30′ 0″
	16	18′ 0″	19′ 1″	20′ 1″	21′ 1″	18′ 9″	19′ 9″	20′ 9″	21′ 7″	22′ 6″	23′ 4″	24′ 1″	24′ 11″	25′ 9″	26′ 5″
	24	15′ 10″	16′ 10″	17′ 9″	18′ 6″	15′ 6″	16′ 4″	17′ 1″	17′ 10″	18′ 7″	19′ 4″	19′ 11″	20′ 7″	21′ 3″	21′ 11″
4 × 6	12	9′ 4″	9′ 10″	10′ 5″	10′ 10″	10′ 9″	11′ 4″	11′ 10″	12′ 4″	12′ 10″	13′ 4″	13′ 10″	14′ 3″	14′ 9″	15′ 1″
	16	8′ 6″	9′ 0″	9′ 5″	9′ 11″	9′ 4″	9′ 10″	10′ 4″	10′ 10″	11′ 3″	11′ 7″	12′ 0″	12′ 5″	12′ 10″	13′ 3″
	24	7′ 5″	7′ 11″	8′ 4″	8′ 9″	7′ 9″	8′ 1″	8′ 6″	8′ 10″	9′ 3″	9′ 6″	9′ 11″	10′ 3″	10′ 6″	10′ 10″
4 × 8	12	12′ 3″	13′ 0″	13′ 9″	14′ 4″	14′ 1″	14′ 11″	15′ 7″	16′ 4″	16′ 11″	17′ 7″	18′ 3″	18′ 10″	19′ 5″	19′ 11″
	16	11′ 3″	11′ 11″	12′ 6″	13′ 1″	12′ 4″	13′ 0″	13′ 7″	14′ 3″	14′ 10″	15′ 5″	15′ 11″	16′ 5″	16′ 11″	17′ 5″
	24	9′ 10″	10′ 6″	11′ 0″	11′ 6″	10′ 1″	10′ 9″	11′ 3″	11′ 9″	12′ 3″	12′ 9″	13′ 1″	13′ 7″	14′ 0″	14′ 5″
4 × 10	12	15′ 5″	16′ 5″	17′ 4″	18′ 0″	17′ 9″	18′ 7″	19′ 6″	20′ 5″	21′ 4″	22′ 0″	22′ 10″	23′ 7″	24′ 4″	25′ 0″
	16	14′ 1″	15′ 0″	15′ 10″	16′ 6″	15′ 6″	16′ 4″	17′ 1″	17′ 11″	18′ 7″	19′ 4″	20′ 0″	20′ 9″	21′ 4″	21′ 11″
	24	12′ 5″	13′ 3″	13′ 11″	14′ 6″	12′ 10″	13′ 6″	14′ 1″	14′ 10″	15′ 5″	16′ C″	16′ 6″	17′ 1″	17′ 7″	18′ 1″

NOTE.—When limited by deflection, the lengths are based on:
Maximum allowable deflection of $\frac{1}{360}$ of span length.
Modulus of elasticity as noted for E.
When determined by bending strength of the piece,
Allowable stress in extreme fiber in bending as noted for f.

Dead load.
- Weight of joist.
- Weight of lath and plaster ceiling (10 lb. per square foot)
- Double thickness of flooring (5 lb. per square foot).

Live load.
- 80 lb. per square foot of floor area with plastered ceiling, or
- 90 lb. per square foot with ceiling unplastered.

TABLE 12.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 80 lb. per square foot with plastered ceiling. Live load 90 lb. per square foot with unplastered ceiling)

These Spans Must Be Compared and Checked with Those in Table 11

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span). Spans limited by horizontal shear (**read carefully**). Having determined by reference to the building code or the table on page 99 the *horizontal shear stress* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine the span limited by the *horizontal shear stress*. Then refer to the tables on page 260 and in the same manner determine the span of the joist limited by its *bending strength* and *use the shorter of the two spans*									
		$S = 70$	$S = 75$	$S = 80$	$S = 85$	$S = 90$	$S = 95$	$S = 100$	$S = 105$	$S = 110$	$S = 120$	$S = 125$
2 × 6	12	8′ 10″	9′ 5″	10′ 0″	10′ 7″	11′ 2″	11′ 10″	12′ 6″	13′ 1″	13′ 8″	15′ 0″	15′ 7″
	16	6′ 7″	7′ 1″	7′ 6″	8′ 0″	8′ 6″	9′ 0″	9′ 5″	9′ 10″	10′ 5″	11′ 4″	11′ 9″
2 × 8	12	11′ 7″	12′ 5″	13′ 2″	14′ 0″	14′ 10″	15′ 8″	16′ 6″	17′ 5″	18′ 2″	19′ 9″	20′ 7″
	16	8′ 9″	9′ 5″	10′ 0″	10′ 7″	11′ 2″	11′ 10″	12′ 6″	13′ 1″	13′ 9″	15′ 0″	15′ 7″
	24	5′ 10″	6′ 4″	6′ 8″	7′ 1″	7′ 7″	8′ 0″	8′ 5″	8′ 9″	9′ 2″	10′ 1″	10′ 6″
2 × 10	12	14′ 6″	15′ 6″	16′ 7″	17′ 7″	18′ 8″	19′ 8″	20′ 8″	21′ 9″	22′ 9″	24′ 10″	25′ 10″
	16	11′ 0″	11′ 9″	12′ 7″	13′ 5″	14′ 2″	14′ 10″	15′ 8″	16′ 6″	17′ 4″	18′ 10″	19′ 8″
	24	7′ 5″	7′ 10″	8′ 6″	9′ 0″	9′ 6″	10′ 1″	10′ 7″	11′ 1″	11′ 8″	12′ 8″	13′ 2″
2 × 12	12	17′ 5″	18′ 8″	19′ 10″	21′ 1″	22′ 5″	23′ 7″	24′ 10″	26′ 1″	27′ 5″	29′ 9″	30′ 0″
	16	13′ 2″	14′ 2″	15′ 1″	16′ 1″	17′ 0″	18′ 0″	18′ 10″	19′ 10″	20′ 9″	22′ 8″	23′ 7″
	24	8′ 10″	9′ 7″	10′ 2″	10′ 10″	11′ 6″	12′ 1″	12′ 9″	13′ 5″	14′ 0″	15′ 4″	16′ 0″
2 × 14	12	20′ 2″	21′ 7″	23′ 0″	24′ 6″	25′ 10″	27′ 5″	28′ 9″	30′ 0″			
	16	15′ 5″	16′ 6″	17′ 7″	18′ 8″	19′ 9″	20′ 10″	22′ 0″	23′ 1″	24′ 2″	26′ 5″	27′ 6″
	24	10′ 5″	11′ 2″	11′ 10″	12′ 8″	13′ 5″	14′ 1″	14′ 10″	15′ 7″	16′ 5″	17′ 10″	18′ 7″
3 × 6	12	13′ 10″	14′ 10″	15′ 10″	16′ 10″	17′ 10″	18′ 10″	19′ 9″	20′ 9″	21′ 9″	23′ 9″	24′ 9″
	16	10′ 6″	11′ 4″	12′ 0″	12′ 9″	13′ 6″	14′ 4″	15′ 1″	15′ 9″	16′ 7″	18′ 1″	18′ 9″
	24	7′ 1″	7′ 7″	8′ 1″	8′ 7″	9′ 1″	9′ 7″	10′ 1″	10′ 7″	11′ 2″	12′ 2″	12′ 8″
3 × 8	12	18′ 2″	19′ 7″	20′ 10″	22′ 2″	23′ 6″	24′ 9″	26′ 1″	27′ 5″	28′ 8″	30′ 0″	
	16	13′ 10″	14′ 10″	15′ 10″	16′ 10″	17′ 10″	18′ 9″	19′ 9″	20′ 9″	21′ 9″	23′ 9″	24′ 9″
	24	9′ 5″	10′ 1″	10′ 8″	11′ 5″	12′ 1″	12′ 8″	13′ 5″	14′ 1″	14′ 9″	16′ 1″	16′ 9″
3 × 10	12	22′ 9″	24′ 5″	26′ 0″	27′ 8″	29′ 4″	30′ 0″					
	16	17′ 5″	18′ 7″	19′ 10″	21′ 1″	22′ 5″	23′ 7″	24′ 9″	26′ 1″	27′ 4″	29′ 9″	30′ 0″
	24	11′ 9″	12′ 7″	13′ 6″	14′ 4″	15′ 2″	16′ 0″	16′ 10″	17′ 8″	18′ 6″	20′ 2″	21′ 1″
3 × 12	12	27′ 2″	29′ 1″	30′ 0″								
	16	20′ 9″	22′ 4″	23′ 9″	25′ 4″	26′ 9″	28′ 4″	29′ 8″	30′ 0″			
	24	14′ 2″	15′ 2″	16′ 2″	17′ 2″	18′ 2″	19′ 2″	20′ 2″	21′ 4″	22′ 4″	24′ 4″	25′ 4″
3 × 14	12	30′ 0″										
	16	24′ 2″	25′ 10″	27′ 7″	29′ 4″	30′ 0″						
	24	16′ 6″	17′ 8″	18′ 10″	20′ 1″	21′ 2″	22′ 5″	23′ 7″	24′ 9″	26′ 0″	28′ 4″	29′ 6″
4 × 6	12	18′ 10″	20′ 4″	21′ 7″	23′ 0″	24′ 4″	25′ 8″	27′ 0″	28′ 5″	29′ 8″	30′ 0″	
	16	14′ 5″	15′ 5″	16′ 5″	17′ 6″	18′ 6″	19′ 6″	20′ 7″	21′ 7″	22′ 7″	24′ 8″	25′ 8″
	24	9′ 8″	10′ 5″	11′ 1″	11′ 9″	12′ 6″	13′ 2″	13′ 10″	14′ 7″	15′ 4″	16′ 8″	17′ 5″
4 × 8	12	24′ 8″	26′ 6″	28′ 2″	30′ 0″							
	16	18′ 10″	20′ 2″	21′ 7″	22′ 10″	24′ 4″	25′ 7″	27′ 0″	28′ 4″	29′ 8″	30′ 0″	
	24	12′ 9″	13′ 8″	14′ 8″	15′ 7″	16′ 6″	17′ 5″	18′ 4″	19′ 2″	20′ 2″	22′ 0″	22′ 10″
4 × 10	12	30′ 0″										
	16	23′ 7″	25′ 2″	26′ 10″	28′ 7″	30′ 0″						
	24	16′ 1″	17′ 2″	18′ 5″	19′ 6″	20′ 8″	21′ 9″	23′ 0″	24′ 1″	25′ 4″	27′ 7″	28′ 8″

NOTE.—The lengths are based on:
Allowable horizontal shear stress as noted for S.

Dead load. { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load. { 80 lb. per square foot of floor area with plastered ceiling, or
90 lb. per square foot with ceiling unplastered.

TABLE 13.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 90 lb. per square foot with plastered ceiling. Live load 100 lb. per square foot with unplastered ceiling)

These Spans Must Be Compared and Checked with Those in Table 14

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)											
		Limited by deflection of $\frac{1}{360}$ of the span Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine span				Spans determined by bending (**Read carefully**) Having determined by reference to the building code or the table on page 99 the allowable *extreme fiber stress in bending* in pounds per square inch for the species and grade of timber used, refer to the column below with the corresponding value to determine the span limited by the *bending strength* of the joist. Then refer to the table on page 264 and in the same manner determine the span of the joist limited by *horizontal shear* and *use the shorter of the two spans*							
		E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000	f = 900	f = 1,000	f = 1,100	f = 1,200	f = 1,300	f = 1,400	f = 1,500	f = 1,600	f = 1,700	f = 1,800
2 × 6	12	6′ 10″	7′ 4″	7′ 8″	8′ 1″	6′ 10″	7′ 2″	7′ 7″	8′ 0″	8′ 4″	8′ 7″	8′ 10″	9′ 2″	9′ 5″	9′ 9″
	16	6′ 4″	6′ 8″	7′ 0″	7′ 4″	6′ 0″	6′ 4″	6′ 7″	6′ 10″	7′ 2″	7′ 6″	7′ 8″	8′ 0″	8′ 2″	8′ 5″
2 × 8	12	9′ 2″	9′ 8″	10′ 4″	10′ 8″	9′ 1″	9′ 8″	10′ 1″	10′ 6″	11′ 0″	11′ 5″	11′ 9″	12′ 2″	12′ 7″	13′ 0″
	16	8′ 4″	8′ 10″	9′ 4″	9′ 9″	8′ 0″	8′ 5″	8′ 9″	9′ 2″	9′ 6″	9′ 10″	10′ 4″	10′ 7″	10′ 10″	11′ 2″
	12	11′ 7″	12′ 4″	13′ 0″	13′ 7″	11′ 6″	12′ 2″	12′ 9″	13′ 4″	13′ 10″	14′ 5″	14′ 10″	15′ 5″	15′ 10″	16′ 4″
2 × 10	16	10′ 7″	11′ 2″	11′ 9″	12′ 5″	10′ 1″	10′ 7″	11′ 1″	11′ 7″	12′ 1″	12′ 7″	13′ 0″	13′ 5″	13′ 9″	14′ 2″
	24	9′ 2″	9′ 9″	10′ 5″	10′ 9″	8′ 2″	8′ 8″	9′ 1″	9′ 6″	9′ 10″	10′ 4″	10′ 7″	11′ 0″	11′ 4″	11′ 8″
	12	14′ 0″	14′ 10″	15′ 8″	16′ 5″	13′ 10″	14′ 8″	15′ 5″	16′ 1″	16′ 8″	17′ 5″	18′ 0″	18′ 7″	19′ 1″	19′ 8″
2 × 12	16	12′ 9″	13′ 7″	14′ 3″	14′ 10″	12′ 1″	12′ 9″	13′ 5″	14′ 0″	14′ 7″	15′ 2″	15′ 8″	16′ 2″	16′ 8″	17′ 2″
	24	11′ 2″	11′ 10″	12′ 6″	13′ 1″	10′ 0″	10′ 6″	11′ 0″	11′ 6″	12′ 0″	12′ 5″	12′ 9″	13′ 4″	13′ 8″	14′ 1″
	12	16′ 5″	17′ 6″	18′ 5″	19′ 3″	16′ 4″	17′ 3″	18′ 0″	18′ 10″	19′ 7″	20′ 4″	21′ 0″	21′ 9″	22′ 5″	23′ 0″
2 × 14	16	15′ 0″	15′ 11″	16′ 10″	17′ 6″	14′ 3″	15′ 0″	15′ 9″	16′ 5″	17′ 1″	17′ 9″	18′ 5″	18′ 11″	19′ 6″	20′ 1″
	24	13′ 3″	14′ 0″	14′ 9″	15′ 5″	11′ 9″	12′ 4″	12′ 11″	13′ 6″	14′ 1″	14′ 7″	15′ 1″	15′ 7″	16′ 1″	16′ 7″
	12	8′ 1″	8′ 7″	9′ 0″	9′ 6″	8′ 9″	9′ 3″	9′ 7″	10′ 0″	10′ 6″	10′ 11″	11′ 4″	11′ 7″	12′ 0″	12′ 4″
3 × 6	16	7′ 5″	7′ 10″	8′ 3″	8′ 7″	7′ 7″	8′ 0″	8′ 5″	8′ 10″	9′ 1″	9′ 6″	9′ 10″	10′ 1″	10′ 5″	10′ 9″
	12	10′ 9″	11′ 5″	12′ 0″	12′ 6″	11′ 6″	12′ 3″	12′ 10″	13′ 4″	14′ 0″	14′ 5″	14′ 11″	15′ 5″	15′ 11″	16′ 4″
3 × 8	16	9′ 10″	10′ 5″	11′ 0″	11′ 6″	10′ 0″	10′ 7″	11′ 1″	11′ 7″	12′ 3″	12′ 7″	13′ 0″	13′ 5″	13′ 10″	14′ 3″
	24	8′ 7″	9′ 1″	9′ 7″	10′ 0″	8′ 3″	8′ 9″	9′ 3″	9′ 6″	10′ 0″	10′ 4″	10′ 9″	11′ 0″	11′ 5″	11′ 9″
	12	13′ 6″	14′ 5″	15′ 1″	15′ 10″	14′ 6″	15′ 4″	16′ 1″	16′ 10″	17′ 6″	18′ 1″	18′ 10″	19′ 5″	20′ 0″	20′ 6″
3 × 10	16	12′ 5″	13′ 3″	13′ 10″	14′ 6″	12′ 9″	13′ 4″	14′ 0″	14′ 9″	15′ 3″	15′ 10″	16′ 5″	16′ 11″	17′ 5″	17′ 11″
	24	10′ 11″	11′ 6″	12′ 1″	12′ 9″	10′ 5″	11′ 0″	11′ 6″	12′ 0″	12′ 7″	13′ 0″	13′ 6″	13′ 11″	14′ 5″	14′ 10″
	12	16′ 4″	17′ 4″	18′ 3″	19′ 1″	17′ 6″	18′ 5″	19′ 4″	20′ 3″	21′ 0″	21′ 10″	22′ 6″	23′ 4″	24′ 0″	24′ 9″
3 × 12	16	14′ 11″	15′ 10″	16′ 9″	17′ 3″	15′ 4″	16′ 1″	16′ 11″	17′ 7″	18′ 5″	19′ 1″	19′ 9″	20′ 5″	21′ 0″	21′ 7″
	24	13′ 1″	13′ 11″	14′ 7″	15′ 4″	12′ 7″	13′ 4″	13′ 11″	14′ 7″	15′ 1″	15′ 9″	16′ 3″	16′ 10″	17′ 4″	17′ 10″
	12	19′ 1″	20′ 3″	21′ 4″	22′ 4″	20′ 5″	21′ 6″	22′ 6″	23′ 6″	24′ 6″	25′ 5″	26′ 4″	27′ 3″	28′ 0″	28′ 10″
3 × 14	16	17′ 6″	18′ 6″	19′ 6″	20′ 5″	17′ 10″	18′ 10″	19′ 9″	20′ 7″	21′ 5″	22′ 3″	23′ 0″	23′ 10″	24′ 6″	25′ 3″
	24	15′ 5″	16′ 4″	17′ 3″	17′ 11″	14′ 9″	15′ 6″	16′ 4″	17′ 0″	17′ 9″	18′ 5″	19′ 0″	19′ 7″	20′ 3″	20′ 10″
	12	9′ 0″	9′ 6″	10′ 0″	10′ 6″	10′ 3″	10′ 9″	11′ 4″	11′ 9″	12′ 3″	12′ 9″	13′ 3″	13′ 7″	14′ 0″	14′ 5″
4 × 6	16	8′ 3″	8′ 9″	9′ 1″	9′ 7″	8′ 11″	9′ 4″	9′ 10″	10′ 3″	10′ 9″	11′ 0″	11′ 5″	11′ 10″	12′ 2″	12′ 6″
	24	7′ 3″	7′ 7″	8′ 0″	8′ 5″	7′ 4″	7′ 9″	8′ 1″	8′ 5″	8′ 10″	9′ 1″	9′ 5″	9′ 9″	10′ 0″	10′ 4″
	12	11′ 11″	12′ 7″	13′ 4″	13′ 11″	13′ 6″	14′ 3″	14′ 11″	15′ 7″	16′ 3″	16′ 10″	17′ 5″	17′ 11″	18′ 6″	19′ 0″
4 × 8	16	10′ 10″	11′ 6″	12′ 1″	12′ 9″	11′ 9″	12′ 5″	13′ 0″	13′ 7″	14′ 1″	14′ 9″	15′ 3″	15′ 9″	16′ 3″	16′ 7″
	24	9′ 6″	10′ 1″	10′ 9″	11′ 1″	9′ 9″	10′ 3″	10′ 9″	11′ 3″	11′ 7″	12′ 1″	12′ 6″	12′ 11″	13′ 4″	13′ 9″
	12	15′ 0″	15′ 11″	16′ 9″	17′ 6″	16′ 11″	17′ 10″	18′ 9″	19′ 6″	20′ 4″	21′ 1″	21′ 10″	22′ 6″	23′ 3″	23′ 11″
4 × 10	16	13′ 9″	14′ 6″	15′ 4″	16′ 1″	14′ 10″	15′ 7″	16′ 4″	17′ 1″	17′ 10″	18′ 5″	19′ 1″	19′ 9″	20′ 4″	20′ 11″
	24	12′ 0″	12′ 10″	13′ 6″	14′ 0″	12′ 3″	12′ 11″	13′ 6″	14′ 1″	14′ 9″	15′ 3″	15′ 9″	16′ 4″	16′ 10″	17′ 4″

NOTE.—When limited by deflection, the lengths are based on:
Maximum allowable deflection of $\frac{1}{360}$ of span length.
Modulus of elasticity as noted for E.
When determined by bending strength of the piece,
Allowable stress in extreme fiber in bending as noted for f.

Dead load. { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load. { 90 lb. per square foot of floor area with plastered ceiling, or
100 lb. per square foot with ceiling unplastered.

TABLE 14.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 90 lb. per square foot with plastered ceiling. Live load 100 lb. per square foot with unplastered ceiling)

These Spans Must Be Compared and Checked with Those in Table 13

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)									
		Spans limited by horizontal shear (**read carefully**) Having determined by reference to the building code or the table on page 99 the *horizontal shear stress* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine the span limited by the *horizontal shear stress*. Then refer to the tables on page 263 and in the same manner determine the span of the joist limited by its *bending strength* and *use the shorter of the two spans*									
		$S = 70$	$S = 75$	$S = 80$	$S = 85$	$S = 90$	$S = 95$	$S = 100$	$S = 105$	$S = 110$	$S = 120$	$S = 125$
2 × 6	12	7′ 10″	8′ 6″	9′ 1″	9′ 7″	10′ 2″	10′ 9″	11′ 4″	11′ 10″	12′ 6″	13′ 7″	14′ 2″
	16	6′ 0″	6′ 5″	6′ 9″	7′ 4″	7′ 8″	8′ 1″	8′ 6″	9′ 0″	9′ 5″	10′ 4″	10′ 8″
2 × 8	12	10′ 6″	11′ 2″	12′ 0″	12′ 8″	13′ 6″	14′ 2″	15′ 0″	15′ 8″	16′ 6″	18′ 0″	18′ 8″
	16	7′ 10″	8′ 6″	9′ 1″	9′ 7″	10′ 2″	10′ 9″	11′ 4″	11′ 10″	12′ 6″	13′ 7″	14′ 2″
2 × 10	12	13′ 2″	14′ 1″	15′ 1″	16′ 0″	17′ 0″	17′ 10″	18′ 9″	19′ 9″	20′ 8″	22′ 7″	23′ 6″
	16	10′ 0″	10′ 8″	11′ 5″	12′ 1″	12′ 9″	13′ 7″	14′ 4″	15′ 0″	15′ 8″	17′ 1″	17′ 9″
	24	6′ 8″	7′ 2″	7′ 8″	8′ 2″	8′ 7″	9′ 1″	9′ 7″	10′ 1″	10′ 7″	11′ 6″	12′ 0″
2 × 12	12	15′ 9″	17′ 0″	18′ 1″	19′ 2″	20′ 5″	21′ 6″	22′ 7″	23′ 9″	24′ 10″	27′ 1″	28′ 4″
	16	12′ 0″	12′ 10″	13′ 8″	14′ 7″	15′ 5″	16′ 4″	17′ 2″	18′ 0″	18′ 10″	20′ 7″	21′ 6″
	24	8′ 1″	8′ 8″	9′ 4″	9′ 9″	10′ 5″	11′ 0″	11′ 7″	12′ 2″	12′ 8″	13′ 10″	14′ 6″
2 × 14	12	18′ 5″	19′ 8″	21′ 0″	22′ 4″	23′ 7″	24′ 10″	26′ 2″	27′ 6″	28′ 9″	30′ 0″	
	16	14′ 0″	15′ 0″	16′ 0″	17′ 0″	18′ 0″	19′ 0″	20′ 0″	21′ 0″	22′ 0″	24′ 0″	25′ 0″
	24	9′ 6″	10′ 1″	10′ 9″	11′ 6″	12′ 2″	12′ 9″	13′ 6″	14′ 2″	14′ 10″	16′ 2″	16′ 10″
3 × 6	12	12′ 7″	13′ 6″	14′ 5″	15′ 4″	16′ 2″	17′ 1″	18′ 0″	18′ 10″	19′ 9″	21′ 7″	22′ 6″
	16	9′ 7″	10′ 2″	10′ 10″	11′ 7″	12′ 4″	13′ 0″	13′ 8″	14′ 4″	15′ 0″	16′ 5″	17′ 1″
3 × 8	12	16′ 7″	17′ 9″	19′ 0″	20′ 2″	21′ 4″	22′ 6″	23′ 8″	24′ 10″	26′ 1″	28′ 6″	29′ 7″
	16	12′ 7″	13′ 6″	14′ 5″	15′ 4″	16′ 2″	17′ 1″	18′ 0″	18′ 10″	19′ 9″	21′ 7″	22′ 6″
	24	8′ 6″	9′ 1″	9′ 8″	10′ 5″	11′ 0″	11′ 7″	12′ 2″	12′ 9″	13′ 5″	14′ 7″	15′ 2″
3 × 10	12	20′ 8″	22′ 2″	23′ 8″	25′ 2″	26′ 8″	28′ 1″	29′ 7″	30′ 0″			
	16	15′ 9″	16′ 10″	18′ 1″	19′ 2″	20′ 4″	21′ 6″	22′ 7″	23′ 8″	24′ 9″	27′ 1″	28′ 2″
	24	10′ 8″	11′ 6″	12′ 2″	13′ 0″	13′ 9″	14′ 6″	15′ 4″	16′ 1″	16′ 9″	18′ 5″	19′ 1″
3 × 12	12	24′ 9″	26′ 6″	28′ 4″	30′ 0″							
	16	18′ 10″	20′ 4″	21′ 7″	23′ 0″	24′ 5″	25′ 8″	27′ 1″	28′ 5″	29′ 9″	30′ 0″	
	24	12′ 10″	13′ 9″	14′ 8″	15′ 7″	16′ 7″	17′ 6″	18′ 5″	19′ 4″	20′ 2″	22′ 1″	23′ 0″
3 × 14	12	28′ 8″	30′ 0″									
	16	22′ 0″	23′ 7″	25′ 2″	26′ 8″	28′ 4″	29′ 10″	30′ 0″				
	24	15′ 0″	16′ 1″	17′ 2″	18′ 2″	19′ 4″	20′ 5″	21′ 6″	22′ 6″	23′ 7″	25′ 8″	26′ 9″
4 × 6	12	17′ 2″	18′ 5″	19′ 8″	20′ 10″	22′ 1″	23′ 4″	24′ 7″	25′ 9″	27′ 0″	29′ 6″	30′ 0″
	16	13′ 1″	14′ 0″	14′ 10″	15′ 10″	16′ 9″	17′ 8″	18′ 8″	19′ 7″	20′ 6″	22′ 5″	23′ 4″
	24	8′ 9″	9′ 6″	10′ 1″	10′ 8″	11′ 4″	12′ 0″	12′ 7″	13′ 2″	13′ 10″	15′ 1″	15′ 9″
4 × 8	12	22′ 6″	24′ 1″	25′ 8″	27′ 4″	28′ 10″	30′ 0″					
	16	17′ 2″	18′ 5″	19′ 7″	20′ 10″	22′ 1″	23′ 4″	24′ 6″	25′ 9″	27′ 0″	29′ 5″	30′ 0″
	24	11′ 8″	12′ 6″	13′ 4″	14′ 1″	15′ 0″	15′ 9″	16′ 7″	17′ 6″	18′ 4″	20′ 0″	20′ 9″
4 × 10	12	28′ 0″	30′ 0″									
	16	21′ 5″	23′ 0″	24′ 6″	26′ 0″	27′ 7″	29′ 1″	30′ 0″				
	24	14′ 7″	15′ 8″	16′ 8″	17′ 9″	18′ 9″	19′ 9″	20′ 10″	21′ 10″	23′ 0″	25′ 1″	26′ 1″

NOTE.—The lengths are based on:
Allowable horizontal shear stress as noted for S.

Dead load { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load { 90 lb. per square foot of floor area with plastered ceiling, or
100 lb. per square foot with ceiling unplastered.

TABLE 15.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 100 lb. per square foot with plastered ceiling. Live load 110 lb. per square foot with unplastered ceiling)

These Spans Must Be Compared and Checked with Those in Table 16

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)												
		Limited by deflection of 1/360 of the span Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine span				Spans determined by bending (**Read carefully**) Having determined by reference to the building code or the table on page 99 the allowable *extreme fiber stress in bending* in pounds per square inch for the species and grade of timber used, refer to the column below with the corresponding value to determine the span limited by the *bending strength* of the joist. **Then** refer to the table on page 266 and in the same manner determine the span of the joist limited by *horizontal shear* and *use the shorter of the two spans*							
		E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000	f = 900	f = 1,000	f = 1,100	f = 1,200	f = 1,300	f = 1,400	f = 1,500	f = 1,600	f = 1,700	f = 1,800
2 × 8	12	8′ 10″	9′ 5″	10′ 0″	10′ 5″	8′ 8″	9′ 2″	9′ 7″	10′ 1″	10′ 6″	10′ 10″	11′ 4″	11′ 8″	12′ 0″	12′ 5″
	16	8′ 1″	8′ 7″	9′ 1″	9′ 6″	7′ 7″	8′ 0″	8′ 5″	8′ 9″	9′ 1″	9′ 6″	9′ 9″	10′ 1″	10′ 5″	10′ 9″
2 × 10	12	11′ 2″	12′ 0″	12′ 7″	13′ 2″	11′ 0″	11′ 8″	12′ 2″	12′ 9″	13′ 4″	13′ 9″	14′ 4″	14′ 8″	15′ 2″	15′ 7″
	16	10′ 2″	10′ 10″	11′ 6″	12′ 0″	9′ 7″	10′ 1″	10′ 7″	11′ 1″	11′ 6″	12′ 0″	12′ 5″	12′ 9″	13′ 2″	13′ 7″
	24	9′ 0″	9′ 6″	10′ 0″	10′ 6″	7′ 10″	8′ 4″	8′ 8″	9′ 1″	9′ 5″	9′ 9″	10′ 1″	10′ 6″	10′ 9″	11′ 1″
2 × 12	12	13′ 7″	14′ 5″	15′ 2″	15′ 10″	13′ 4″	14′ 1″	14′ 8″	15′ 5″	16′ 0″	16′ 7″	17′ 2″	17′ 9″	18′ 4″	18′ 10″
	16	12′ 5″	13′ 2″	13′ 10″	14′ 6″	11′ 7″	12′ 2″	12′ 9″	13′ 5″	14′ 0″	14′ 6″	15′ 0″	15′ 6″	16′ 0″	16′ 5″
	24	10′ 10″	11′ 6″	12′ 2″	12′ 8″	9′ 6″	10′ 1″	10′ 6″	11′ 0″	11′ 5″	11′ 10″	12′ 4″	12′ 8″	13′ 1″	13′ 6″
2 × 14	12	16′ 0″	16′ 11″	17′ 10″	18′ 9″	15′ 7″	16′ 6″	17′ 4″	18′ 0″	18′ 10″	19′ 6″	20′ 1″	20′ 10″	21′ 5″	22′ 1″
	16	14′ 6″	15′ 6″	16′ 4″	17′ 0″	13′ 7″	14′ 5″	15′ 1″	15′ 9″	16′ 5″	17′ 0″	17′ 7″	18′ 1″	18′ 9″	19′ 4″
	24	12′ 10″	13′ 7″	14′ 4″	14′ 11″	11′ 3″	11′ 10″	12′ 5″	12′ 10″	13′ 6″	14′ 0″	14′ 6″	14′ 11″	15′ 5″	15′ 10″
3 × 6	12	7′ 11″	8′ 4″	8′ 10″	9′ 3″	8′ 5″	8′ 10″	9′ 3″	9′ 7″	10′ 0″	10′ 5″	10′ 10″	11′ 1″	11′ 6″	11′ 10″
	16	7′ 3″	7′ 7″	8′ 0″	8′ 5″	7′ 3″	7′ 9″	8′ 0″	8′ 5″	8′ 9″	9′ 1″	9′ 5″	9′ 9″	10′ 0″	10′ 3″
	12	10′ 6″	11′ 1″	11′ 7″	12′ 3″	11′ 0″	11′ 9″	12′ 3″	12′ 10″	13′ 5″	13′ 10″	14′ 4″	14′ 9″	15′ 3″	15′ 9″
3 × 8	16	9′ 6″	10′ 1″	10′ 9″	11′ 1″	9′ 7″	10′ 1″	10′ 7″	11′ 1″	11′ 9″	12′ 0″	12′ 5″	12′ 10″	13′ 3″	13′ 7″
	24	8′ 4″	8′ 11″	9′ 4″	9′ 9″	7′ 11″	8′ 5″	8′ 10″	9′ 3″	9′ 7″	9′ 10″	10′ 3″	10′ 6″	10′ 11″	11′ 3″
3 × 10	12	13′ 3″	14′ 0″	14′ 9″	15′ 5″	13′ 11″	14′ 9″	15′ 5″	16′ 1″	16′ 9″	17′ 5″	18′ 0″	18′ 7″	19′ 1″	19′ 9″
	16	12′ 0″	12′ 9″	13′ 5″	14′ 0″	12′ 3″	12′ 10″	13′ 3″	14′ 0″	14′ 7″	15′ 3″	15′ 9″	16′ 3″	16′ 9″	17′ 3″
	24	10′ 6″	11′ 3″	11′ 10″	12′ 4″	10′ 0″	10′ 6″	11′ 0″	11′ 7″	12′ 0″	12′ 5″	12′ 11″	13′ 4″	13′ 9″	14′ 1″
3 × 12	12	15′ 10″	16′ 10″	17′ 9″	18′ 6″	16′ 9″	17′ 9″	18′ 6″	19′ 4″	20′ 1″	20′ 11″	21′ 7″	22′ 4″	23′ 0″	23′ 9″
	16	14′ 6″	15′ 5″	16′ 3″	16′ 11″	14′ 7″	15′ 5″	16′ 3″	16′ 11″	17′ 7″	18′ 3″	18′ 11″	19′ 6″	20′ 1″	20′ 9″
	24	12′ 9″	13′ 6″	14′ 3″	14′ 11″	12′ 0″	12′ 9″	13′ 4″	13′ 11″	13′ 6″	15′ 0″	15′ 7″	16′ 1″	16′ 7″	17′ 1″
3 × 14	12	18′ 6″	19′ 9″	20′ 9″	21′ 9″	19′ 6″	20′ 7″	21′ 7″	22′ 7″	23′ 6″	24′ 5″	25′ 3″	26′ 1″	26′ 11″	27′ 7″
	16	16′ 11″	18′ 0″	19′ 0″	19′ 10″	17′ 1″	18′ 0″	18′ 11″	19′ 9″	20′ 6″	21′ 4″	22′ 1″	22′ 10″	23′ 6″	24′ 3″
	24	14′ 11″	15′ 10″	16′ 9″	17′ 6″	14′ 1″	14′ 11″	15′ 7″	16′ 4″	17′ 0″	17′ 7″	18′ 3″	18′ 10″	19′ 5″	19′ 11″
4 × 6	12	8′ 9″	9′ 4″	9′ 9″	10′ 3″	9′ 9″	10′ 4″	10′ 10″	11′ 4″	11′ 9″	12′ 3″	12′ 7″	13′ 0″	13′ 5″	13′ 10″
	16	8′ 0″	8′ 5″	8′ 11″	9′ 4″	8′ 6″	8′ 11″	9′ 5″	9′ 10″	10′ 3″	10′ 7″	11′ 0″	11′ 4″	11′ 9″	12′ 0″
	24	7′ 0″	7′ 5″	7′ 10″	8′ 1″	7′ 0″	7′ 4″	7′ 9″	8′ 1″	8′ 5″	8′ 9″	9′ 0″	9′ 4″	9′ 7″	9′ 10″
4 × 8	12	11′ 6″	12′ 3″	12′ 11″	13′ 6″	12′ 11″	13′ 7″	14′ 3″	14′ 11″	15′ 6″	16′ 1″	16′ 7″	17′ 3″	17′ 9″	18′ 3″
	16	10′ 6″	11′ 3″	11′ 10″	12′ 4″	11′ 4″	11′ 11″	12′ 5″	13′ 0″	13′ 6″	14′ 0″	14′ 6″	15′ 0″	15′ 6″	15′ 11″
	24	9′ 4″	9′ 10″	10′ 5″	10′ 10″	9′ 4″	9′ 9″	10′ 3″	10′ 9″	11′ 1″	11′ 7″	12′ 0″	12′ 5″	12′ 9″	13′ 1″
4 × 10	12	14′ 6″	15′ 5″	16′ 4″	17′ 0″	16′ 3″	17′ 1″	17′ 11″	18′ 9″	19′ 6″	20′ 3″	20′ 11″	21′ 7″	22′ 4″	22′ 11″
	16	13′ 4″	14′ 1″	14′ 11″	15′ 7″	14′ 3″	14′ 11″	15′ 9″	16′ 5″	17′ 0″	17′ 9″	18′ 4″	18′ 11″	19′ 6″	20′ 0″
	24	11′ 9″	12′ 5″	13′ 1″	13′ 9″	11′ 9″	12′ 4″	12′ 11″	13′ 6″	14′ 0″	14′ 7″	15′ 1″	15′ 7″	16′ 1″	16′ 6″

NOTE.—When limited by deflection, the lengths are based on:
Maximum allowable deflection of 1/360 of span length.
Modulus of elasticity as noted for E.
When determined by bending strength of the piece,
Allowable stress in extreme fiber in bending as noted for f.

Dead load { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load { 100 lb. per square foot of floor area with plastered ceiling, or
110 lb. per square foot with ceiling unplastered.

TABLE 16.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 100 lb. per square foot with plastered ceiling. Live load 110 lb. per square foot with unplastered ceiling)

These Spans Must Be Compared and Checked with Those in Table 15

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)										
		Spans limited by horizontal shear **(read carefully)** Having determined by reference to the building code or the table on page 99 the *horizontal shear stress* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine the span limited by the *horizontal shear stress.* Then refer to the tables on page 265 and in the same manner determine the span of the joist limited by its *bending strength* and *use the shorter of the two spans*										
		$S = 70$	$S = 75$	$S = 80$	$S = 85$	$S = 90$	$S = 95$	$S = 100$	$S = 105$	$S = 110$	$S = 120$	$S = 125$
2 × 8	12	9′ 7″	10′ 4″	11′ 0″	11′ 8″	12′ 5″	13′ 0″	13′ 8″	14′ 5″	15′ 1″	16′ 6″	17′ 2″
	16	7′ 4″	7′ 9″	8′ 4″	8′ 9″	9′ 4″	9′ 10″	10′ 5″	10′ 10″	11′ 5″	12′ 5″	13′ 0″
2 × 10	12	12′ 1″	12′ 10″	13′ 9″	14′ 8″	15′ 6″	16′ 5″	17′ 4″	18′ 1″	19′ 0″	20′ 8″	21′ 7″
	16	9′ 1″	9′ 9″	10′ 6″	11′ 1″	11′ 9″	12′ 5″	13′ 1″	13′ 8″	14′ 5″	15′ 8″	16′ 4″
	24	6′ 2″	6′ 7″	7′ 0″	7′ 6″	7′ 10″	8′ 4″	8′ 9″	9′ 2″	9′ 8″	10′ 6″	11′ 0″
2 × 12	12	14′ 6″	15′ 7″	16′ 7″	17′ 7″	18′ 8″	19′ 8″	20′ 8″	21′ 9″	22′ 9″	24′ 10″	25′ 10″
	16	11′ 0″	11′ 9″	12′ 7″	13′ 5″	14′ 2″	14′ 10″	15′ 8″	16′ 6″	17′ 4″	18′ 10″	19′ 8″
	24	7′ 5″	7′ 10″	8′ 6″	9′ 0″	9′ 6″	10′ 1″	10′ 7″	11′ 1″	11′ 8″	12′ 8″	13′ 2″
2 × 14	12	16′ 9″	18′ 1″	19′ 4″	20′ 6″	21′ 8″	22′ 10″	24′ 1″	25′ 4″	26′ 6″	28′ 10″	30′ 0″
	16	12′ 9″	13′ 8″	14′ 7″	15′ 7″	16′ 6″	17′ 5″	18′ 4″	19′ 2″	20′ 1″	22′ 0″	22′ 10″
	24	8′ 8″	9′ 4″	9′ 10″	10′ 6″	11′ 1″	11′ 8″	12′ 5″	13′ 0″	13′ 7″	14′ 9″	15′ 6″
3 × 6	12	11′ 7″	12′ 5″	13′ 2″	14′ 0″	14′ 10″	15′ 8″	16′ 6″	17′ 4″	18′ 2″	19′ 9″	20′ 8″
	16	8′ 9″	9′ 5″	10′ 0″	10′ 7″	11′ 4″	11′ 10″	12′ 6″	13′ 1″	13′ 9″	15′ 0″	15′ 7″
3 × 8	12	15′ 2″	16′ 4″	17′ 5″	18′ 6″	19′ 7″	20′ 8″	21′ 8″	22′ 9″	23′ 10″	26′ 1″	27′ 2″
	16	11′ 7″	12′ 5″	13′ 2″	14′ 0″	14′ 10″	15′ 8″	16′ 6″	17′ 4″	18′ 2″	19′ 9″	20′ 7″
	24	7′ 9″	8′ 5″	8′ 10″	9′ 6″	10′ 0″	10′ 7″	11′ 1″	11′ 8″	12′ 4″	13′ 5″	13′ 10″
3 × 10	12	19′ 0″	20′ 5″	21′ 9″	23′ 1″	24′ 6″	25′ 9″	27′ 2″	28′ 7″	29′ 10″	30′ 0″	
	16	14′ 6″	15′ 6″	16′ 7″	17′ 7″	18′ 7″	19′ 8″	20′ 8″	21′ 9″	22′ 9″	24′ 10″	25′ 10″
	24	9′ 9″	10′ 6″	11′ 2″	11′ 10″	12′ 7″	13′ 4″	14′ 0″	14′ 8″	15′ 5″	16′ 9″	17′ 6″
3 × 12	12	22′ 9″	24′ 5″	26′ 0″	27′ 7″	29′ 4″	30′ 0″					
	16	17′ 5″	18′ 7″	19′ 10″	21′ 7″	22′ 5″	23′ 7″	24′ 9″	26′ 1′	27′ 4″	29′ 9″	31′ 1″
	24	11′ 9″	12′ 7″	13′ 6″	14′ 4″	15′ 2″	16′ 0″	16′ 10″	17′ 8″	18′ 6″	20′ 2″	21′ 1″
3 × 14	12	26′ 5″	28′ 4″	30′ 0″								
	16	20′ 2″	21′ 8″	23′ 1″	24′ 7″	26′ 0″	27′ 5″	28′ 10″	30′ 0″			
	24	13′ 9″	14′ 9″	15′ 8″	16′ 8″	17′ 8″	18′ 8″	19′ 8″	20′ 8″	21′ 7″	23′ 7″	24′ 7″
4 × 6	12	15′ 9″	16′ 10″	18′ 0″	19′ 2″	20′ 4″	21′ 5″	22′ 6″	23′ 8″	24′ 9″	27′ 0″	28′ 2″
	16	12′ 0″	12′ 9″	13′ 8″	14′ 6″	15′ 5″	16′ 2″	17′ 1″	18′ 0″	18′ 9″	20′ 6″	21′ 5″
	24	8′ 1″	8′ 8″	9′ 2″	9′ 9″	10′ 5″	11′ 0″	11′ 6″	12′ 1″	12′ 8″	13′ 9″	14′ 5″
4 × 8	12	20′ 8″	22′ 1″	23′ 7″	25′ 1″	26′ 7″	28′ 0″	29′ 6″	30′ 0″			
	16	15′ 9″	16′ 10″	18′ 0″	19′ 1″	20′ 4″	21′ 5″	22′ 6″	23′ 7″	24′ 9″	27′ 0″	28′ 1″
	24	10′ 8″	11′ 5″	12′ 2″	13′ 0″	13′ 8″	14′ 6″	15′ 2″	16′ 0″	16′ 9″	18′ 4″	19′ 1″
4 × 10	12	25′ 8″	27′ 7″	29′ 5″	30′ 0″							
	16	19′ 8″	21′ 1″	22′ 6″	23′ 10″	25′ 4″	26′ 8″	28′ 1″	29′ 7″	30′ 0″		
	24	13′ 5″	14′ 5″	15′ 4″	16′ 4″	17′ 2″	18′ 2″	19′ 1″	20′ 1″	21′ 1″	23′ 0″	23′ 10″

NOTE.—The lengths are based on:
Allowable horizontal shear stress as noted for *S*.

Dead load { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load { 100 lb. per square foot of floor area with plastered ceiling, or
110 lb. per square foot with ceiling unplastered.

TABLE 17.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 125 lb. per square foot with plastered ceiling. Live load 135 lb. per square foot with unplastered ceiling)

These Spans Must Be Compared and Checked with Those in Table 18

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)												
		Limited by deflection of 1/360 of the span Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine span				Spans determined by bending **(Read carefully)** Having determined by reference to the building code or the table on page 99 the allowable *extreme fiber stress in bending* in pounds per square inch for the species and grade of timber used, refer to the column below with the corresponding value to determine the span limited by the *bending strength* of the joist. **Then** refer to the table on page 268 and in the same manner determine the span of the joist limited by *horizontal shear* and *use the shorter of the two spans*							
		E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000	f = 900	f = 1,000	f = 1,100	f = 1,200	f = 1,300	f = 1,400	f = 1,500	f = 1,600	f = 1,700	f = 1,800
2 × 8	12	8′ 4″	8′ 10″	9′ 4″	9′ 9″	8′ 0″	8′ 5″	8′ 9″	9′ 2″	9′ 6″	9′ 10″	10′ 2″	10′ 7″	10′ 10″	11′ 2″
	16	7′ 7″	8′ 1″	8′ 6″	9′ 0″	6′ 10″	7′ 2″	7′ 7″	8′ 0″	8′ 4″	8′ 7″	8′ 10″	9′ 2″	9′ 6″	9′ 9″
2 × 10	12	10′ 7″	11′ 2″	11′ 9″	12′ 5″	10′ 1″	10′ 7″	11′ 1″	11′ 7″	12′ 1″	12′ 7″	13′ 0″	13′ 5″	13′ 9″	14′ 2″
	16	9′ 7″	10′ 6″	10′ 9″	11′ 4″	8′ 8″	9′ 2″	9′ 8″	10′ 1″	10′ 6″	10′ 10″	11′ 4″	11′ 8″	12′ 0″	12′ 5″
2 × 12	12	12′ 9″	13′ 7″	14′ 4″	14′ 10″	12′ 1″	12′ 9″	13′ 5″	14′ 0″	14′ 7″	15′ 2″	15′ 8″	16′ 2″	16′ 8″	17′ 2″
	16	11′ 7″	12′ 5″	13′ 0″	13′ 7″	10′ 6″	11′ 1″	11′ 8″	12′ 2″	12′ 8″	13′ 2″	13′ 7″	14′ 1″	14′ 6″	14′ 10″
2 × 14	12	15′ 0″	15′ 11″	16′ 10″	17′ 6″	14′ 3″	15′ 0″	15′ 9″	16′ 5″	17′ 1″	17′ 9″	18′ 5″	18′ 11″	19′ 6″	20′ 1″
	16	13′ 9″	14′ 6″	15′ 4″	16′ 0″	12′ 5″	13′ 0″	13′ 9″	14′ 4″	14′ 11″	15′ 6″	16′ 0″	16′ 6″	17′ 0″	17′ 6″
	24	12′ 0″	12′ 10″	13′ 5″	14′ 1″	10′ 1″	10′ 9″	11′ 3″	11′ 9″	12′ 3″	12′ 9″	13′ 1″	13′ 7″	14′ 0″	14′ 5″
3 × 6	12	7′ 5″	7′ 10″	8′ 3″	8′ 7″	7′ 6″	8′ 0″	8′ 5″	8′ 10″	9′ 1″	9′ 6″	9′ 10″	10′ 1″	10′ 5″	10′ 9″
	16	6′ 9″	7′ 1″	7′ 6″	7′ 10″	6′ 7″	6′ 11″	7′ 4″	7′ 7″	7′ 11″	8′ 3″	8′ 6″	8′ 10″	9′ 1″	9′ 4″
3 × 8	12	9′ 10″	10′ 5″	11′ 0″	11′ 6″	10′ 0″	10′ 7″	11′ 1″	11′ 7″	12′ 2″	12′ 7″	13′ 0″	13′ 5″	13′ 10″	14′ 3″
	16	8′ 11″	9′ 6″	10′ 0″	10′ 5″	8′ 10″	9′ 3″	9′ 9″	10′ 1″	10′ 7″	10′ 11″	11′ 4″	11′ 9″	12′ 0″	12′ 5″
	24	7′ 10″	8′ 4″	8′ 10″	9′ 3″	7′ 3″	7′ 6″	7′ 6″	8′ 4″	8′ 9″	9′ 0″	9′ 4″	9′ 7″	9′ 11″	10′ 1″
3 × 10	12	12′ 5″	13′ 1″	13′ 10″	14′ 6″	12′ 9″	13′ 4″	14′ 0″	14′ 9″	15′ 3″	15′ 10″	16′ 5″	16′ 11″	17′ 5″	17′ 11″
	16	11′ 4″	12′ 0″	12′ 7″	13′ 3″	11′ 0″	11′ 9″	12′ 3″	12′ 10″	13′ 4″	13′ 10″	14′ 4″	14′ 9″	15′ 3″	15′ 7″
	24	9′ 11″	10′ 6″	11′ 1″	11′ 7″	9′ 1″	9′ 7″	10′ 0″	10′ 6″	10′ 11″	11′ 4″	11′ 9″	12′ 1″	12′ 6″	12′ 10″
3 × 12	12	14′ 11″	15′ 10″	16′ 9″	17′ 6″	15′ 4″	16′ 1″	16′ 11″	17′ 7″	18′ 5″	19′ 1″	19′ 9″	20′ 5″	21′ 0″	21′ 7″
	16	13′ 7″	14′ 6″	15′ 3″	15′ 11″	13′ 4″	14′ 0″	14′ 9″	15′ 5″	16′ 0″	16′ 7″	17′ 3″	17′ 10″	18′ 4″	18′ 10″
	24	12′ 0″	12′ 9″	13′ 5″	14′ 0″	11′ 0″	11′ 7″	12′ 1″	12′ 7″	13′ 3″	13′ 9″	14′ 1″	14′ 7″	15′ 1″	15′ 6″
3 × 14	12	17′ 6″	18′ 6″	19′ 6″	20′ 5″	17′ 10″	18′ 10″	19′ 9″	20′ 7″	21′ 5″	22′ 3″	23′ 0″	23′ 10″	24′ 6″	25′ 3″
	16	15′ 11″	16′ 11″	17′ 10″	18′ 7″	15′ 7″	16′ 5″	17′ 3″	18′ 0″	18′ 9″	19′ 5″	20′ 1″	20′ 10″	21′ 5″	22′ 0″
	24	14′ 0″	14′ 10″	15′ 9″	16′ 4″	12′ 10″	13′ 6″	14′ 3″	14′ 10″	15′ 5″	16′ 0″	16′ 7″	17′ 1″	17′ 7″	18′ 3″
4 × 6	12	8′ 3″	8′ 9″	9′ 1″	9′ 7″	8′ 11″	9′ 4″	9′ 10″	10′ 3″	10′ 9″	11′ 0″	11′ 5″	11′ 10″	12′ 3″	12′ 6″
	16	7′ 5″	7′ 11″	8′ 4″	8′ 9″	7′ 9″	8′ 1″	8′ 6″	8′ 11″	9′ 4″	9′ 7″	9′ 11″	10′ 4″	10′ 7″	10′ 11″
	24	6′ 6″	7′ 0″	7′ 4″	7′ 7″	6′ 4″	6′ 9″	7′ 0″	7′ 4″	7′ 7″	7′ 11″	8′ 3″	8′ 5″	8′ 9″	8′ 11″
4 × 8	12	10′ 11″	11′ 6″	12′ 3″	12′ 9″	11′ 9″	12′ 5″	13′ 0″	13′ 7″	14′ 1″	14′ 9″	15′ 3″	15′ 9″	16′ 3″	16′ 7″
	16	9′ 11″	10′ 6″	11′ 1″	11′ 7″	10′ 3″	10′ 10″	11′ 4″	11′ 10″	12′ 4″	12′ 10″	13′ 3″	13′ 9″	14′ 1″	14′ 6″
	24	8′ 9″	9′ 3″	9′ 9″	10′ 3″	8′ 5″	8′ 11″	9′ 4″	9′ 9″	10′ 1″	10′ 6″	10′ 11″	11′ 3″	11′ 7″	11′ 11″
4 × 10	12	13′ 9″	14′ 7″	15′ 4″	16′ 0″	14′ 10″	15′ 7″	16′ 4″	17′ 1″	17′ 10″	18′ 5″	19′ 1″	19′ 9″	20′ 4″	20′ 11″
	16	12′ 6″	13′ 4″	14′ 0″	14′ 7″	12′ 11″	13′ 7″	14′ 4″	14′ 11″	15′ 6″	16′ 1″	16′ 9″	17′ 3″	17′ 9″	18′ 3″
	24	11′ 0″	11′ 9″	12′ 4″	12′ 11″	10′ 7″	11′ 3″	11′ 9″	12′ 4″	12′ 10″	13′ 4″	13′ 9″	14′ 1″	14′ 7″	15′ 0″

NOTE.—When limited by deflection, the lengths are based on:
Maximum allowable deflection of 1/360 of span length.
Modulus of elasticity as noted for E.
When determined by bending strength of the piece.
Allowable stress in extreme fiber in bending as noted for f.

Dead load { Weight of joist. Weight of lath and plaster ceiling (10 lb. per square foot). Double thickness of flooring (5 lb. per square foot).

Live load. { 125 lb. per square foot of floor area with plastered ceiling, or 135 lb. per square foot with ceiling unplastered.

TABLE 18.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 125 lb. per square foot with plastered ceiling. Live load 135 lb. per square foot with unplastered ceiling)

These Spans Must Be Compared and Checked with Those in Table 17

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)									
		Spans limited by horizontal shear (read carefully) Having determined by reference to the building code or the table on page 99 the *horizontal shear stress* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine the span limited by the *horizontal shear stress.* Then refer to the tables on page 267 and in the same manner determine the span of the joist limited by its *bending strength* and *use the shorter of the two spans*									
		$S = 70$	$S = 75$	$S = 80$	$S = 85$	$S = 90$	$S = 95$	$S = 100$	$S = 105$	$S = 110$	$S = 120$	$S = 125$
2 × 8	12	7′ 10″	8′ 6″	9′ 1″	9′ 7″	10′ 2″	10′ 9″	11′ 4″	11′ 10″	12′ 6″	13′ 7″	14′ 2″
	16	6′ 0″	6′ 5″	6′ 9″	7′ 4″	7′ 8″	8′ 1″	8′ 7″	9′ 0″	9′ 5″	10′ 4″	10′ 8″
2 × 10	12	10′ 0″	10′ 8″	11′ 5″	12′ 1″	12′ 9″	13′ 7″	14′ 4″	15′ 0″	15′ 8″	17′ 1″	17′ 9″
	16	7′ 6″	8′ 1″	8′ 7″	9′ 2″	9′ 8″	10′ 2″	10′ 9″	11′ 4″	11′ 10″	12′ 10″	13′ 6″
2 × 12	12	12′ 0″	12′ 10″	13′ 8″	14′ 7″	15′ 5″	16′ 4″	17′ 2″	18′ 0″	18′ 10″	20′ 7″	21′ 6″
	16	9′ 1″	9′ 8″	10′ 5″	11′ 0″	11′ 8″	12′ 4″	13′ 0″	13′ 7″	14′ 4″	15′ 7″	16′ 2″
2 × 14	12	14′ 0″	15′ 0″	16′ 0″	17′ 0″	18′ 0″	19′ 0″	20′ 0″	21′ 0″	22′ 0″	24′ 0″	25′ 0″
	16	10′ 7″	11′ 5″	12′ 1″	12′ 10″	13′ 7″	14′ 5″	15′ 1″	15′ 10″	16′ 8″	18′ 2″	18′ 10″
	24	7′ 1″	7′ 8″	8′ 2″	8′ 8″	9′ 2″	9′ 8″	10′ 2″	10′ 8″	11′ 2″	12′ 2″	12′ 9″
3 × 6	12	9′ 7″	10′ 2″	10′ 10″	11′ 7″	12′ 4″	13′ 0″	13′ 8″	14′ 4″	15′ 0″	16′ 5″	17′ 1″
	16	7′ 2″	7′ 8″	8′ 4″	8′ 9″	9′ 4″	9′ 9″	10′ 4″	10′ 9″	11′ 5″	12′ 5″	12′ 10″
3 × 8	12	12′ 7″	13′ 6″	14′ 5″	15′ 4″	16′ 2″	17′ 1″	18′ 0″	18′ 10″	19′ 9″	21′ 7″	22′ 6″
	16	9′ 7″	10′ 2″	10′ 10″	11′ 7″	12′ 4″	13′ 0″	13′ 7″	14′ 4″	15′ 0″	16′ 5″	17′ 1″
	24	6′ 5″	6′ 10″	7′ 5″	7′ 9″	8′ 4″	8′ 8″	9′ 2″	9′ 7″	10′ 1″	11′ 0″	11′ 6″
3 × 10	12	15′ 9″	16′ 10″	18′ 1″	19′ 2″	20′ 4″	21′ 6″	22′ 7″	23′ 8″	24′ 9″	27′ 1″	28′ 2″
	16	12′ 0″	12′ 10″	13′ 8″	14′ 7″	15′ 5″	16′ 4″	17′ 2″	18′ 0″	18′ 10″	20′ 7″	21′ 5″
	24	8′ 1″	8′ 8″	9′ 4″	9′ 9″	10′ 5″	11′ 0″	11′ 7″	12′ 2″	12′ 8″	13′ 10″	14′ 6″
3 × 12	12	18′ 10″	20′ 4″	21′ 7″	23′ 0″	24′ 5″	25′ 8″	27′ 1″	28′ 5″	29′ 9″	30′ 0″	
	16	14′ 5″	15′ 6″	16′ 6″	17′ 6″	18′ 6″	19′ 7″	20′ 7″	21′ 7″	22′ 8″	24′ 8″	25′ 9″
	24	9′ 9″	10′ 6″	11′ 2″	11′ 10″	12′ 6″	13′ 2″	13′ 10″	14′ 7″	15′ 4″	16′ 8″	17′ 5″
3 × 14	12	22′ 0″	23′ 7″	25′ 2″	26′ 8″	28′ 4″	29′ 10″	30′ 0″				
	16	16′ 9″	18′ 0″	19′ 2″	20′ 5″	21′ 7″	22′ 9″	24′ 0″	25′ 2″	26′ 5″	28′ 9″	30′ 0″
	24	11′ 5″	12′ 2″	13′ 0″	13′ 9″	14′ 8″	15′ 6″	16′ 4″	17′ 1″	17′ 10″	19′ 6″	20′ 4″
4 × 6	12	13′ 1″	14′ 0″	14′ 10″	15′ 10″	16′ 9″	17′ 8″	18′ 8″	19′ 7″	20′ 6″	22′ 5″	23′ 4″
	16	9′ 10″	10′ 7″	11′ 4″	12′ 0″	12′ 8″	13′ 5″	14′ 1″	14′ 9″	15′ 7″	17′ 0″	17′ 8″
	24	6′ 8″	7′ 1″	7′ 7″	8′ 1″	8′ 7″	9′ 0″	9′ 6″	10′ 0″	10′ 6″	11′ 5″	11′ 10″
4 × 8	12	17′ 2″	18′ 5″	19′ 7″	20′ 10″	22′ 1″	23′ 4″	24′ 6″	25′ 9″	27′ 0″	29′ 5″	30′ 0″
	16	13′ 1″	14′ 0″	14′ 10″	15′ 10″	16′ 9″	17′ 8″	18′ 7″	19′ 7″	20′ 6″	22′ 5″	23′ 4″
	24	8′ 9″	9′ 5″	10′ 1″	10′ 8″	11′ 4″	12′ 0″	12′ 7″	13′ 2″	13′ 10″	15′ 1″	15′ 8″
4 × 10	12	21′ 5″	23′ 0″	24′ 6″	26′ 0″	27′ 7″	29′ 1″	30′ 0″				
	16	16′ 4″	17′ 6″	18′ 8″	19′ 9″	21′ 0″	22′ 2″	23′ 4″	24′ 6″	25′ 8″	28′ 0″	29′ 2″
	24	11′ 1″	11′ 10″	12′ 8″	13′ 6″	14′ 4″	15′ 0″	15′ 9″	16′ 7″	17′ 5″	19′ 0″	19′ 9″

NOTE.—The lengths are based on:
Allowable horizontal shear stress as noted for *S*.

Dead load { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load. { 125 lb. per square foot of floor area with plastered ceiling, or
135 lb. per square foot with ceiling unplastered.

TABLE 19.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 150 lb. per square foot with plastered ceiling. Live load 160 lb. per square foot with unplastered ceiling)

These Spans Must Be Compared and Checked with Those in Table 20

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)												
		Limited by deflection of 1/360 of the span. Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine span				Spans determined by bending (**Read carefully**). Having determined by reference to the building code or the table on page 99 the allowable *extreme fiber stress in bending* in pounds per square inch for the species and grade of timber used, refer to the column below with the corresponding value to determine the span limited by the *bending strength* of the joist. Then refer to the table on page 270 and in the same manner determine the span of the joist limited by *horizontal shear* and *use the shorter of the two spans*							
		E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000	f = 900	f = 1,000	f = 1,100	f = 1,200	f = 1,300	f = 1,400	f = 1,500	f = 1,600	f = 1,700	f = 1,800
2 × 8	12	7′ 10″	8′ 5″	8′ 9″	9′ 2″	7′ 4″	7′ 8″	8′ 1″	8′ 5″	8′ 9″	9′ 1″	9′ 5″	9′ 8″	10′ 1″	10′ 4″
	16	7′ 2″	7′ 7″	8′ 0″	8′ 5″	6′ 5″	6′ 8″	7′ 0″	7′ 4″	7′ 7″	7′ 10″	8′ 2″	8′ 6″	8′ 8″	9′ 0″
2 × 10	12	10′ 0″	10′ 7″	11′ 2″	11′ 8″	9′ 4″	9′ 8″	10′ 2″	10′ 8″	11′ 1″	11′ 7″	12′ 0″	12′ 5″	12′ 9″	13′ 1″
	16	9′ 1″	9′ 8″	10′ 2″	10′ 8″	8′ 0′	8′ 6″	8′ 10″	9′ 4″	9′ 7″	10′ 0″	10′ 5″	10′ 8″	11′ 0″	11′ 5″
2 × 12	12	12′ 1″	12′ 10″	13′ 6″	14′ 2″	11′ 2″	11′ 9″	12′ 5″	12′ 10″	13′ 5″	13′ 10″	14′ 5″	15′ 0″	15′ 5″	15′ 10″
	16	11′ 0″	11′ 8″	12′ 4″	12′ 10″	9′ 8″	10′ 2″	10′ 9″	11′ 2″	11′ 8″	12′ 2″	12′ 7″	13′ 0″	13′ 5″	13′ 9″
2 × 14	12	14′ 3″	15′ 1″	15′ 11″	16′ 7″	13′ 3″	13′ 11″	14′ 6″	15′ 3″	15′ 10″	16′ 5″	16′ 11″	17′ 6″	18′ 1″	18′ 7″
	16	13′ 0″	13′ 10″	14′ 6″	15′ 7″	11′ 5″	12′ 0″	12′ 7″	13′ 3″	13′ 9″	14′ 3″	14′ 10″	15′ 3″	15′ 9″	16′ 3″
3 × 6	12	7′ 0″	7′ 5″	7′ 10 ′	8′ 3″	7′ 0″	7′ 5″	7′ 9″	8′ 1″	8′ 5″	8′ 9″	9′ 1″	9′ 4″	9′ 7″	9′ 11″
	16	6′ 4″	6′ 9″	7′ 1″	7′ 6″	6′ 1″	6′ 5″	6′ 9″	7′ 0″	7′ 4″	7′ 7″	7′ 11″	8′ 1″	8′ 5″	8′ 7″
3 × 8	12	9′ 4″	9′ 11″	10′ 5″	10′ 11″	9′ 4″	9′ 10″	10′ 4″	10′ 9″	11′ 4″	11′ 7″	12′ 0″	12′ 5″	12′ 10″	13′ 3″
	16	8′ 5″	9′ 0″	9′ 6″	9′ 11″	8′ 1″	8′ 6″	8′ 11″	9′ 4″	9′ 10″	10′ 1″	10′ 5″	10′ 10″	11′ 1″	11′ 5″
3 × 10	12	11′ 9″	12′ 6″	13′ 1″	13′ 9″	11′ 9″	12′ 5″	13′ 0″	13′ 6″	14′ 1″	14′ 7″	15′ 1″	15′ 9″	16′ 1″	16′ 7″
	16	10′ 9″	11′ 5″	12′ 0″	12′ 6″	10′ 3″	10′ 10″	11′ 4″	11′ 10″	12′ 4″	12′ 9″	13′ 3″	13′ 7″	14′ 0″	14′ 6″
	24	9′ 5″	10′ 0″	10′ 6″	11′ 0″	8′ 5″	8′ 10″	9′ 4″	9′ 9″	10′ 0″	10′ 5″	10′ 10″	11′ 3″	11′ 6″	11′ 10″
3 × 12	12	14′ 3″	15′ 0″	15′ 10″	16′ 7″	14′ 1″	14′ 11″	15′ 7″	16′ 4″	17′ 0″	17′ 7″	18′ 3″	18′ 10″	19′ 5″	20′ 0″
	16	12′ 11″	13′ 9″	14′ 6″	15′ 1″	12′ 4″	13′ 0″	13′ 7″	14′ 3″	14′ 10″	15′ 5″	15′ 11″	16′ 5″	16′ 11″	17′ 5″
	24	11′ 4″	12′ 0″	12′ 9″	13′ 4″	10′ 1″	10′ 9″	11′ 3″	11′ 9″	12′ 3″	12′ 7″	13′ 1″	13′ 6″	13′ 11″	14′ 4″
3 × 14	12	16′ 7″	17′ 7″	18′ 6″	19′ 5″	16′ 6″	17′ 5″	18′ 4″	19′ 1″	19′ 10″	20′ 7″	21′ 4″	22′ 0″	22′ 9″	23′ 5″
	16	15′ 1″	16′ 1″	16′ 11″	17′ 9″	14′ 5″	15′ 3″	15′ 11″	16′ 7″	17′ 4″	18′ 0″	18′ 7″	19′ 3″	19′ 10″	20′ 5″
	24	13′ 4″	14′ 1″	14′ 11″	15′ 6″	11′ 11″	12′ 6″	13′ 1″	13′ 9″	14′ 3″	14′ 10″	15′ 4″	15′ 10″	16′ 4″	16′ 10″
4 × 6	12	7′ 10″	8′ 3″	8′ 9″	9′ 1″	8′ 3″	8′ 9″	9′ 1″	9′ 6″	9′ 10″	10′ 3″	10′ 7″	10′ 11″	11′ 4″	11′ 7″
	16	7′ 1″	7′ 6″	7′ 11″	8′ 4″	7′ 1″	7′ 6″	7′ 11″	8′ 3″	8′ 6″	8′ 11″	9′ 3″	9′ 6″	9′ 10″	10′ 1″
	24	6′ 3″	6′ 7″	6′ 11″	7′ 3″	5′ 10″	6′ 3″	6′ 6″	6′ 10″	7′ 0″	7′ 4″	7′ 6″	7′ 10″	8′ 1″	8′ 3″
4 × 8	12	10′ 4″	10′ 11″	11′ 6″	12′ 0″	10′ 11″	11′ 5″	12′ 0″	12′ 7″	13′ 1″	13′ 7″	14′ 0″	14′ 6″	14′ 11″	15′ 5″
	16	9′ 5″	10′ 0″	10′ 6″	11′ 0″	9′ 6″	10′ 0″	10′ 6″	10′ 11″	11′ 5″	11′ 10″	12′ 3″	12′ 7″	13′ 0″	13′ 5″
	24	8′ 3″	8′ 10″	9′ 3″	9′ 7″	7′ 9″	8′ 3″	8′ 7″	9′ 0″	9′ 4″	9′ 9″	10′ 0″	10′ 4″	10′ 9″	11′ 0″
4 × 10	12	13′ 0″	13′ 10″	14′ 6″	15′ 3″	13′ 9″	14′ 5″	15′ 1″	15′ 10″	16′ 6″	17′ 1″	17′ 9″	18′ 3″	18′ 10″	19′ 5″
	16	11′ 11″	12′ 7″	13′ 4″	13′ 11″	11′ 11″	12′ 7″	13′ 3″	13′ 10″	14′ 5″	14′ 11″	15′ 5″	15′ 11″	16′ 5″	16′ 11″
	24	10′ 5″	11′ 1″	11′ 9″	12′ 3″	9′ 10″	10′ 4″	10′ 11″	11′ 4″	11′ 10″	12′ 3″	12′ 9″	13′ 1″	13′ 6′	13′ 11″

NOTE.—When limited by deflection, the lengths are based on:
Maximum allowable deflection of 1/360 of span length.
Modulus of elasticity as noted for E.
When determined by bending strength of the piece,
Allowable stress in extreme fiber in bending as noted for f.

Dead load { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load. { 150 lb. per square foot of floor area with plastered ceiling, **or**
160 lb. per square foot with ceiling unplastered.

TABLE 20.—MAXIMUM SPANS FOR FLOOR JOISTS, UNIFORMLY LOADED

(Live load 150 lb. per square foot with plastered ceiling. Live load 160 lb. per square foot with unplastered ceiling)

These Spans Must Be Compared and Checked with Those in Table 19

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)									
		Spans limited by horizontal shear (**read carefully**) Having determined by reference to the building code or the table on page 99 the *horizontal shear stress* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine the span limited by the *horizontal shear stress.* **Then** refer to the tables on page 269 and in the same manner determine the span of the joist limited by its *bending strength* and *use the shorter of the two spans*									
		$S = 70$	$S = 75$	$S = 80$	$S = 85$	$S = 90$	$S = 95$	$S = 100$	$S = 105$	$S = 110$	$S = 120$	$S = 125$
2 × 8	12	6′ 9″	7′ 2″	7′ 8″	8′ 2″	8′ 8″	9′ 2″	9′ 8″	10′ 1″	10′ 7″	11′ 7″	12′ 1″
	16	5′ 1″	5′ 6″	5′ 9″	6′ 2″	6′ 6″	6′ 10″	7′ 4″	7′ 7″	8′ 0″	8′ 8″	9′ 1″
2 × 10	12	8′ 6″	9′ 1″	9′ 8″	10′ 4″	10′ 10″	11′ 7″	12′ 2″	12′ 9″	13′ 5″	14′ 7″	15′ 2″
	16	6′ 5″	6′ 10″	7′ 4″	7′ 9″	8′ 4″	8′ 8″	9′ 2″	9′ 7″	10′ 1″	11′ 0″	11′ 6″
2 × 12	12	10′ 2″	11′ 0″	11′ 8″	12′ 5″	13′ 2″	13′ 10″	14′ 7″	15′ 5″	16′ 1″	17′ 7″	18′ 4″
	16	7′ 8″	8′ 4″	8′ 10″	9′ 5″	10′ 0″	10′ 6″	11′ 1″	11′ 7″	12′ 2″	13′ 4″	13′ 9″
2 × 14	12	11′ 10″	12′ 9″	13′ 7″	14′ 6″	15′ 4″	16′ 2″	17′ 0″	17′ 10″	18′ 9″	20′ 6″	21′ 4″
	16	9′ 0″	9′ 8″	10′ 4″	11′ 0″	11′ 7″	12′ 4″	12′ 10″	13′ 7″	14′ 2″	15′ 6″	16′ 1″
3 × 6	12	8′ 1″	8′ 8″	9′ 4″	9′ 10″	10′ 6″	11′ 1″	11′ 7″	12′ 2″	12′ 9″	14′ 0″	14′ 7″
	16	6′ 2″	6′ 7″	7′ 0″	7′ 6″	7′ 10″	8′ 4″	8′ 9″	9′ 2″	9′ 8″	10′ 6″	11′ 0″
3 × 8	12	10′ 9″	11′ 6″	12′ 4″	13′ 1″	13′ 9″	14′ 7″	15′ 5″	16′ 2″	16′ 10″	18′ 6″	19′ 2″
	16	8′ 1″	8′ 8″	9′ 4″	9′ 10″	10′ 6″	11′ 0″	11′ 7″	12′ 2″	12′ 9″	14′ 0″	14′ 6″
3 × 10	12	13′ 6″	14′ 6″	15′ 5″	16′ 5″	17′ 5″	18′ 4″	19′ 4″	20′ 4″	21′ 2″	23′ 2″	24′ 1″
	16	10′ 2″	11′ 0″	11′ 8″	12′ 5″	13′ 2″	13′ 10″	14′ 7″	15′ 5″	16′ 1″	17′ 7″	18′ 4″
	24	6′ 10″	7′ 5″	7′ 10″	8′ 5″	8′ 10″	9′ 5″	9′ 10″	10′ 5″	10′ 9″	11′ 9″	12′ 4″
3 × 12	12	16′ 2″	17′ 5″	18′ 6″	19′ 8″	20′ 10″	22′ 0″	23′ 2″	24′ 4″	25′ 6″	27′ 9″	29′ 0″
	16	12′ 4″	13′ 2″	14′ 1″	15′ 0″	15′ 9″	16′ 8″	17′ 7″	18′ 6″	19′ 5″	21′ 1″	22′ 0″
	24	8′ 4″	8′ 10″	9′ 6″	10′ 1″	10′ 8″	11′ 4″	11′ 10″	12′ 6″	13′ 1″	14′ 4″	14′ 10″
3 × 14	12	18′ 10″	20′ 2″	21′ 7″	22′ 10″	24′ 4″	25′ 7″	27′ 0″	28′ 4″	29′ 8″	30′ 0″	
	16	14′ 5″	15′ 5″	16′ 5″	17′ 5″	18′ 6″	19′ 6″	20′ 6″	21′ 6″	22′ 7″	24′ 7″	25′ 8″
	24	9′ 8″	10′ 5″	11′ 1″	11′ 9″	12′ 6″	13′ 2″	13′ 10″	14′ 7″	15′ 4″	16′ 8″	17′ 5″
4 × 6	12	11′ 2″	11′ 10″	12′ 8″	13′ 6″	14′ 4″	15′ 1″	15′ 10″	16′ 8″	17′ 6″	19′ 1″	19′ 10″
	16	8′ 5″	9′ 0″	9′ 7″	10′ 2″	10′ 9″	11′ 5″	12′ 1″	12′ 8″	13′ 4″	14′ 6″	15′ 1″
	24	5′ 8″	6′ 1″	6′ 6″	6′ 10″	7′ 4″	7′ 8″	8′ 1″	8′ 6″	8′ 10″	9′ 8″	10′ 1″
4 × 8	12	14′ 8″	15′ 8″	16′ 9″	17′ 9″	18′ 10″	19′ 10″	21′ 0″	22′ 0″	23′ 1″	25′ 2″	26′ 2″
	16	11′ 1″	11′ 10″	12′ 8″	13′ 6″	14′ 4″	15′ 1″	15′ 10″	16′ 8″	17′ 6″	19′ 1″	19′ 10″
	24	7′ 6″	8′ 0″	8′ 7″	9′ 1″	9′ 8″	10′ 2″	10′ 8″	11′ 4″	11′ 9″	12′ 10″	13′ 5″
4 × 10	12	18′ 5″	19′ 8″	21′ 0″	22′ 4″	23′ 7″	24′ 10″	26′ 4″	27′ 7″	28′ 10″	30′ 0″	
	16	14′ 0″	15′ 0″	16′ 0″	17′ 0″	18′ 0″	19′ 0″	20′ 0″	21′ 0″	22′ 0″	24′ 0″	25′ 0″
	24	9′ 6″	10′ 1″	10′ 9″	11′ 6″	12′ 2″	12′ 9″	13′ 6″	14′ 2″	14′ 10″	16′ 2″	16′ 10″

NOTE.—The lengths are based on:
Allowable horizontal shear stress as noted for S.

Dead load { Weight of joist.
Weight of lath and plaster ceiling (10 lb. per square foot).
Double thickness of flooring (5 lb. per square foot).

Live load { 150 lb. per square foot of floor area with plastered ceiling, or
160 lb. per square foot with ceiling unplastered.

TABLE 21.—MAXIMUM SPANS FOR CEILING JOISTS AND ATTIC FLOOR JOISTS, UNIFORMLY LOADED

Nominal size of joists, inches	Spacing of joists center to center, inches	Maximum allowable lengths between supports (clear span)							
		Limited by deflection of $\frac{1}{360}$ of the span. Having determined by reference to the building code or the table on page 99 the allowable *modulus of elasticity* in pounds per square inch for the species of timber used, refer to the column below with the corresponding value to determine maximum safe span							
		Ceiling joists				Attic floor joists, live load 20 lb. per square foot			
		E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000	E = 1,000,000	E = 1,200,000	E = 1,400,000	E = 1,600,000
2 × 4	12	9′ 4″	10′ 0″	10′ 6″	11′ 0″	6′ 6″	7′ 0″	7′ 4″	7′ 8″
	16	8′ 7″	9′ 2″	9′ 8″	10′ 0″	5′ 11″	6′ 3″	6′ 8″	6′ 11″
	24	7′ 7″	8′ 1″	8′ 6″	8′ 11″	5′ 3″	5′ 7″	5′ 10″	6′ 1″
2 × 6	12	14′ 2″	15′ 5″	15′ 10″	16′ 7″	10′ 0″	10′ 9″	11′ 3″	11′ 0″
	16	13′ 3″	14′ 0″	14′ 8″	15′ 4″	9′ 1″	9′ 8″	10′ 2″	10′ 8″
	24	11′ 8″	12′ 5″	13′ 0″	13′ 8″	8′ 1″	8′ 7″	9′ 0″	9′ 7″
2 × 8	12	18′ 6″	19′ 8″	20′ 0″	21′ 8″	13′ 4″	14′ 2″	14′ 11″	15′ 7″
	16	17′ 2″	18′ 3″	19′ 3″	20′ 2″	12′ 1″	12′ 10″	13′ 6″	14′ 2″
	24	15′ 4″	16′ 4″	17′ 2″	18′ 0″	10′ 9″	11′ 5″	12′ 0″	12′ 7″
2 × 10	12	23′ 0″	24′ 5″	25′ 8″	26′ 10″	16′ 9″	17′ 9″	18′ 9″	19′ 7″
	16	21′ 4″	22′ 9″	24′ 0″	25′ 0″	15′ 3″	16′ 2″	17′ 0″	17′ 9″
	24	19′ 3″	20′ 5″	21′ 6″	22′ 6″	13′ 7″	14′ 5″	15′ 2″	15′ 10″
2 × 12	12	27′ 2″	28′ 11″	30′ 0″		20′ 0″	21′ 4″	22′ 6″	23′ 6″
	16	25′ 6″	27′ 0″	28′ 6″	29′ 9″	18′ 4″	19′ 5″	20′ 6″	21′ 5″
	24	23′ 0″	24′ 5″	25′ 9″	26′ 10″	16′ 4″	17′ 4″	18′ 3″	19′ 1″

NOTE.—The lengths are based on:

Maximum allowable deflection of $\frac{1}{360}$ of span length.

Modulus of elasticity as noted for E.

Ceiling joists:

Dead load: Weight of joists plus plaster ceiling (10 lb. per square foot).

Live load: None.

Attic floor joists:

Dead load: Weight of joist.

Weight of lath and plaster ceiling (10 lb. per square foot).

Single thickness of flooring (2.5 lb. per square foot).

Live load: 20 lb. per square foot of floor area.

These tables can readily be used to find the required joist size and spacing for a given span. To do this, refer to the table for the load to be supported, and, under the stress permitted for the species and grade of lumber used, locate the given span length, then read across to the size and spacing of joist for that span.

For stresses and loads intermediate between those given in the tables the span may safely be selected by interpolation.

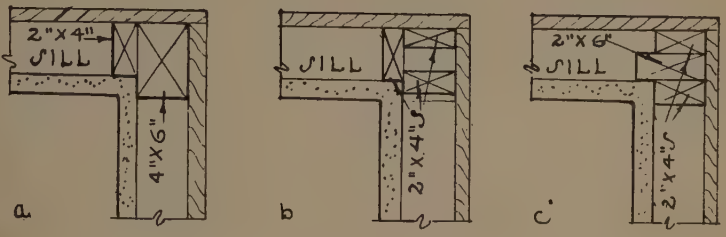
Spans are given in most instances for two limiting conditions—one span being so limited that the deflection under the calculated load will not exceed $\frac{1}{360}$ the span length, and the other determined by the bending strength of the piece. The deflection should be limited to prevent cracks, where ceilings are covered with some hard, inelastic material such as plaster. Where ceilings are not so covered and where a small amount of deflection is not objectionable, the span length may be determined by the bending strength or by the allowable horizontal shear stress (whichever governs) instead of by the stiffness of the member.

When using the tables to determine the span lengths under heavier loads, the reader is cautioned to note that in addition to spans for deflection and bending there are included spans based on horizontal shear stress and to follow carefully the instructions on the tables. The spans limited by horizontal shear, and those given for bending, must be checked against each other for the particular load involved. Thus, for a live load of 150 lb. per square foot, it is essential to find both the span length limited by the allowable horizontal shear stress and that limited by the allowable stress in extreme fiber, and then to use the shorter of the two. This is necessary because a joist might be of adequate size to support the load as far as bending strength is concerned but might fail because it had a greater span than was justified by the allowable stress in shear; or, if the span was selected for shear, it might be greater than that permitted for bending. The ratio of extreme fiber stress to horizontal shear is not constant for all species, some species having a relatively high extreme fiber stress in bending, with a comparatively low allowable horizontal shear stress, while for other species the ratio is quite different. Also, when designing for stiffness, that is, to limit the deflection of the joist under the assumed live load, it is necessary to check the deflection, bending, and shear spans and use the shortest of the three.

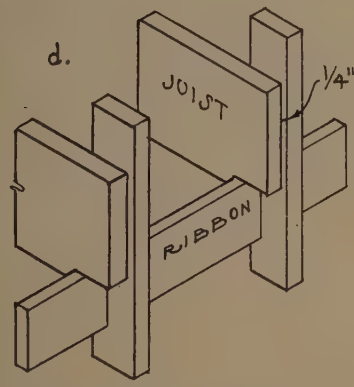
OUTSIDE FRAMEWORK

Exterior walls should be built of not less than 2 by 4-in. wood-framed construction, with the supporting members spaced not to exceed 16 in. on centers and set with the 4-in. dimension at right angles to the face of the wall.

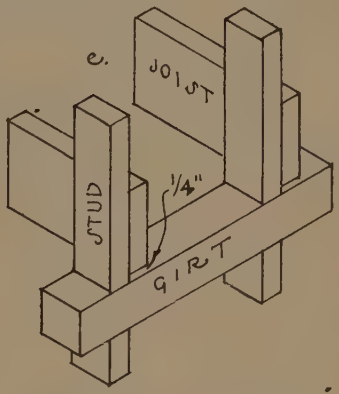
Corner posts should rest on the top of and be spiked to the sills and should extend to the plate at the eaves. Common sizes for small houses



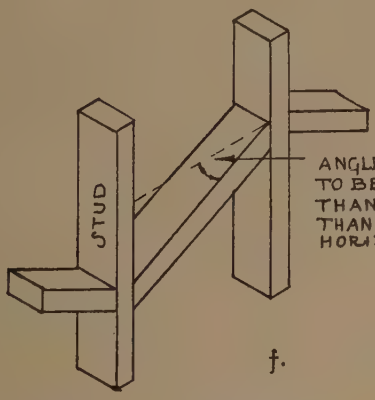
FRAMING OF STUDS AT CORNER.



DETAIL OF RIBBON BALLOON FRAME.



DETAIL OF GIRT BRACED FRAME



DETAIL OF BRACING BETWEEN STUDS.

OUTSIDE FRAMEWORK

Plate 6.

are 4 by 4 in. and 4 by 6 in. (Fig. *a*, *Plate* 6), although two 2 by 4 in. spiked together are frequently used for small buildings not to be plastered; but this is rather clumsy construction and is not recommended. A nailing surface must be furnished if the walls are to be lathed and plastered. A good method is to add a stud alongside of the post. Blocks 1 ft. long may also be necessary at the bottom of the corner post to provide a nailing base for the inside baseboard. Figures *b* and *c* illustrate two methods of providing nailing surfaces when built-up posts are used.

The usual minimum size for studs in houses is 2 by 4 in., though in larger buildings 2 by 6-in. lumber is often used. Larger studs make plumbing installation easier and, in fact, are often required to conceal soil pipes. A 16-in. spacing is usual for all studding. Experience indicates that this spacing provides sufficient strength and stiffness for the walls and furnishes a suitable nailing base for 4-ft. laths and for each floor joist.

In balloon construction, the studs reach from the sills to the eave plates and must be notched at the second story height to carry the ledger board or ribbon which supports the second-story joists. Ledger boards should be not less than 1 by 4 in. and should be cut into the studs and securely nailed with not less than two 10-d. nails to each stud.

In braced-frame and western-framed construction, the studs extend only from the sill to the second-floor joists and stud caps, respectively; the second-floor studs rest either on the caps or on subflooring and extend to the plate at the eaves.

Figures *d* and *e* show approved methods of supporting floor joists at the second-floor level, in both balloon and braced-frame construction. All members are well spiked to each other. Note the ribbon notched into the stud and the joists notched over the ribbon in Fig. *d*. Also, note ¼-in. clearance between the ends of the joists and the outside of the studs, so that there will be no danger of the joist's projecting beyond the stud and bulging the sheathing. Obviously, it is best to provide material that has been manufactured in accurate lengths, with ends sawed at 90 deg., thus eliminating much hand labor and enabling the architect or builder to figure on using exact commercial lengths of lumber.

Proper bracing of a frame building is of great importance. In balloon and in western framing, the diagonal sheathing contributes considerably to the bracing effect, as it breaks the rectangular framing into triangles and affords a certain amount of structural stability. If the sheathing is placed horizontally, which is desirable with a stucco finish, diagonal braces approximately 1 by 6 in. must be cut into the studs at both the top and the bottom of all corners. Good construction requires such braces in any case.

Plate 2 shows 2 by 4-in. heavy bracing in modern braced-frame construction. It is believed by many that each diagonal brace should be one continuous piece rather than three or four in the same line, as shown, thus

cutting the studs instead of the bracing. Such construction might have been preferable in the old braced-frame type of building where the studs were mortised into the braces. But, on account of the weakening of the stud supports, it is doubtful if such continuous bracing is as satisfactory where the studs are simply toenailed to the diagonal bracing.

Where the studs are capped at the second-floor level with a girt, a solid 4 by 4 or two 2 by 4-in. pieces are generally used. When a solid girt and a solid corner post are used, the girt is butted against the post and supported by a block or, in the case of heavy loads, by a steel angle, lag screwed into place. When built-up corner posts are used, the girt rests on one of the component studs. At the eaves the studs are capped with a top plate of the same width as the studs. Two pieces of 2 by 4-in. lumber nailed on top of the studs are generally used.

Bridging, as indicated in Fig. *f*, *Plate* 6, should be placed between the studs midway between floor levels to add stiffness to the frame; it also provides fire stopping.

It is exceedingly important that the building be thoroughly tied, to resist the thrust of the rafters. When it is not feasible to tie the building together at the foot of the rafters, the thrust may be transferred to the end walls by a system of diagonal bracing on the underside of the rafters. This, in reality, makes trusses of the two halves of the roof, which are nailed together at the peak. In small barns, this system of bracing may be used to eliminate the objectionable ties across the center of the barn; in a garage, the end containing the doors will not get out of shape if a proper system of bracing is used on the roof or underneath the ties, and if the other three walls are well braced.

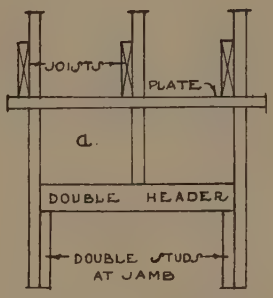
FRAMING AROUND OPENINGS

It is customary to double the studding at the sides of all vertical openings and to use the header at the top of the opening as a cap for the inside studs rather than to insert it between them and secure it with nails.

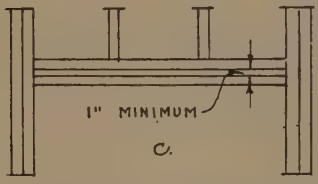
This arrangement gives a solid support to the header, which must bear most of the load from the studs directly over the openings.

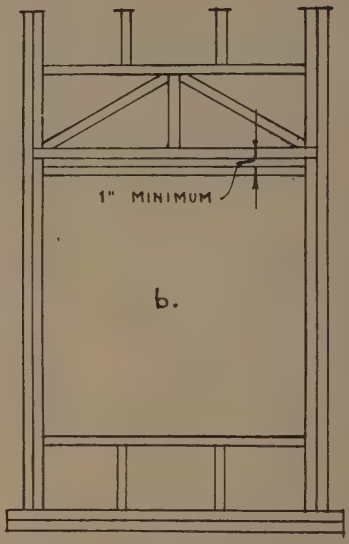
Narrow door or window openings of not more than two stud spaces may be framed as shown in Fig. *a*, *Plate* 7.

Where the openings are wider, diagonal bracing or trussing is commonly used to give the required strength. This method is illustrated by Fig. *b*. Another method is simply to leave a 1-in. space at the head of an opening so that whatever sag develops by reason of the weight above will not be transmitted to the lower 2 by 4-in. headpiece and cause the window or door to bind. A still stronger arrangement, shown in Fig. *d*, is used for wide openings such as double doors or large windows. The headers are set with the larger dimension vertical, as indicated, which, of course,

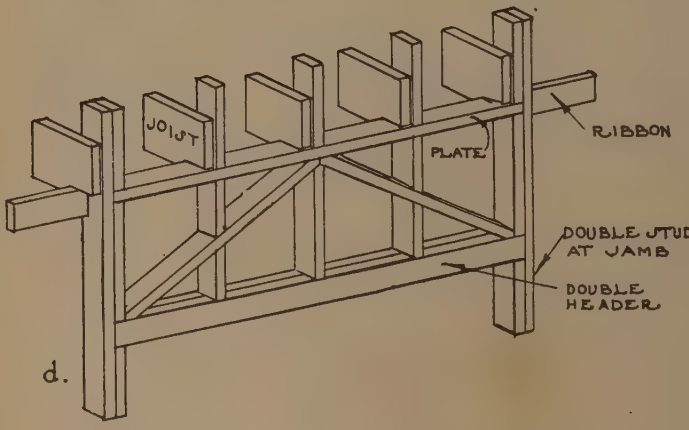


FRAMING AT NARROW OPENING.





FRAMING DETAILS FOR WIDE WINDOW OPENINGS.



FRAMING DETAIL AT WIDE OPENING.

FRAMING · AROUND · OPENINGS

Plate 7.

obviates the necessity for the horizontal clearance space under the main header.

All of these methods are considered sound practice.

WINDOW AND DOOR CONSTRUCTION

In general, a window may be said to consist of three parts, namely, the frame, the sash, and the inside finish. Each part is usually described separately in the specifications. A more detailed discussion of window sash and finish will be found in Chap. IX under Millwork.

The point to be stressed in connection with the framing of window openings is the sealing of the joints around the window frame. In this connection, it should be noted that weatherstrips have been developed which not only aid materially in making all types of windows and doors water-tight but also effect substantial savings in fuel, by preventing air leakage. Figure 73 shows a type of window frame that provides effective sealing at the joints. In this detail, blind casings are used at the sides and top, both on the outside and on the inside of the frame. These casings are nailed to the window studs at the sides and to the header at the top of the opening. The wall sheathing butts against the edge of the outside blind casing, and the joint between the two is sealed by building paper and the outside finish casing. The inside blind casing acts as a gage for the plaster, which is worked up to it, the joint being concealed by the inside finish casing. The space between the sill and the header is filled with caulking material and further closed up with a strip plowed into the sill. The top of the sill is rabbeted to receive the sash, and the siding is let into a groove in the underside.

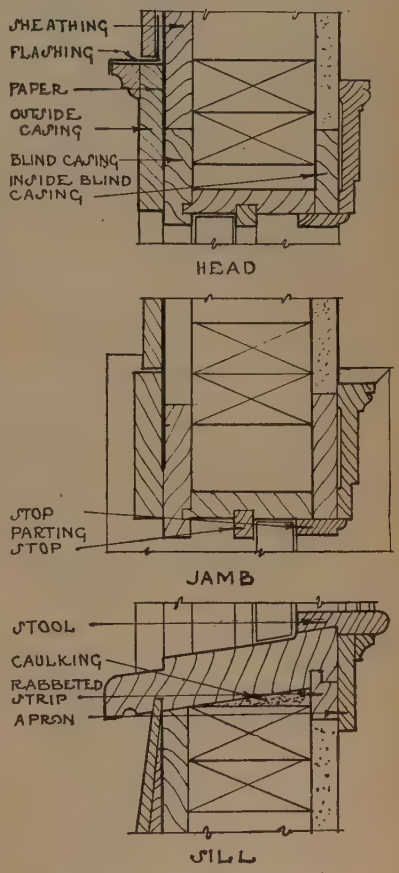


Fig. 73.—Window frame detail.

It is also important that the joint between the drip caps (the molding across the top of the frame) and the siding be made absolutely tight.

This is accomplished by the use of metal flashing, nailed to the drip cap and bent up to extend behind the siding.

Although this illustration shows a frame for ordinary, double-hung sash, the same general principles apply to the construction and fitting of frames for stationary or casement sash.

It is important that weather-resisting species be used for all parts of the window frame which are exposed to the weather. White pine has always been preferred for such use, where it could be obtained at a reasonable price; but at present, southern pine, Douglas fir, western red cedar, California white and sugar pine, cypress, and redwood are all generally used for this purpose. Southern pine or Douglas fir are commonly used for pulley stiles, because they are relatively hard and wear better under the friction of the sash than the other woods enumerated. The pulley stile should never be painted but simply oiled or stained.

Concealed portions of the frame may be made of the most common wood of the locality, but all window-frame material should be well seasoned and protected from rain or snow until it is installed.

Windows in masonry walls are set in much the same way as windows in frame construction; the general principles to be applied are similar for all windows. The frame should be held securely in position, in order that there may be no binding when the sash is raised or lowered and no undue amount of play to permit the sash to rattle during winds. Furthermore, all joints should be tightly covered, to exclude the weather. Caulking around the frames, and wherever there is a chance for air to leak in, aids materially in making a weather-tight job.

When doors are to be hung to open inward, it is best to have the inner edge of the frame set flush with the line of the finished plaster. The joint between the frame and the plaster can then be covered with the casing. In dwelling houses, it is well to provide room for hanging a screen door on the outside of the frame

SECURING DOOR BUCKS AND FRAMES

In the ordinary wood-framed building, door frames are held in place by blocks and wedges driven between the studding and the jamb of the door. In masonry walls, door frames are often secured by fastening them to nailing blocks set in the masonry. This is not a particularly satisfactory method, for, although it may be found all right at first, the wooden blocks, if not seasoned, are apt to shrink and become loosened from the masonry, with the result that the frame will no longer fit tightly. A better method of fastening the door frame to the masonry is to use metal strips screwed to the back of the jamb and set 6 or 8 in. into the masonry. This will avoid any chance of shrinkage and will hold the door frame firmly in place.

In tile partitions, or wherever wood door bucks are employed, they may be secured to the partition by means of metal anchors, fastened to the bucks and inserted in the partition joints. At least three anchors should be used at each side, to obtain a rigidity sufficient to overcome the loosening effect of slamming doors.

PORCHES

No new principles of framing are involved in the construction of the ordinary porch. The floor is preferably supported by masonry piers, although wooden posts of such durable woods as cedar, redwood, or cypress give satisfaction in numerous instances. The space under the porch is usually enclosed with latticework. At times, a solid masonry wall is used instead of piers and latticework, but this is poor practice unless adequate ventilation is provided for, as it shuts off all ventilation under the porch and so engenders rot.

The porch flooring should run perpendicular to the wall of the house and be so pitched as to allow water to drain off quickly.

Two methods of laying floors are in use. One is to use square-edge boards spaced about $\frac{3}{16}$ in. apart. This method is designed for regions of heavy rainfall to prevent water from seeping into joints.

In the other method, matched flooring is used. The tongue and groove of each board should be painted with white lead and oil to make the joints water tight, and the floor given a pitch of at least 1 in. in 6 ft.

PARTITION CONSTRUCTION

The partitions in buildings of ordinary construction are usually built of 2 by 4-in. studding, spaced either 12 or 16 in. on centers, giving five or four nailings, respectively, to the laths. For bearing partition, and also where the stories exceed 9 ft. 6 in. in height, the stud spacing should not exceed 12 in., as 16-in. spacing does not give sufficient stiffness for first-class buildings. For partitions exceeding 11 ft. in height, 6-in. studding should be used. A partition built of 2 by 6-in. studding, spaced 16 in. on centers, is much stiffer than one built of 2 by 4-in. studding, 12 in. on centers; but it contains about 12 per cent additional lumber. A spacing of 16 in., however, does not make so stiff a job of plastering, and for this reason a spacing of 12 in. is to be preferred in the better class of houses, no matter what the size of the studding may be. Much more room for heating pipes and soil pipes is allowed with 6-in. studding than with 4-in. studding.

In putting up partitions it is important to build them so that there will be as little settling as possible from shrinkage. This is especially true of bearing partitions which act as a support for the joists in the second and third (or upper) stories and so influence settlement throughout the building. The ordinary method of constructing such partitions,

particularly in buildings not superintended by an architect, is indicated in Fig. *a*, *Plate* 8, which shows the studding of a first-story and of the lower part of a second-story bearing partition. From an inspection of this particular figure it will be seen that there are 37 in. of horizontal lumber between the top of the basement piers and the bottom of the second-story studding; and, as the ordinary lumber, unless thoroughly seasoned, will shrink across the grain about ½ in. per foot, at the end of 1 or 2 years it would probably be found that the second-story partition had settled 1½ in. and that the third story or attic joists had settled with it.

Two-thirds of this shrinkage can be avoided simply by resting the first-floor studs directly upon the basement girder and the second-floor studs upon the plate which caps the first-floor studs. This correct method of framing is illustrated in Fig. *b*, where the partition runs across the joists. Note the headers cut in between the studs to act as fire stops and so prevent flames from passing readily from one side of the partition to the other, under the flooring. In Fig. *c* is shown a bearing partition parallel to the joists.

A method of supporting non-bearing partitions which have no supporting partitions below is illustrated in Fig. *d*. Two joists are spaced about 8 in. apart. Solid bridging blocks are nailed securely between the joists with the grain horizontal so that the shrinkage will not pull them away. For additional stiffness, a double row of cross-bridging should be used on the outside of the joists; a still better method is to use bridging blocks, say 2 by 6 in., between the joists and to support these blocks on 2 by 3-in. cleats nailed to the inside of the joists. Since shrinkage effect is localized in a non-bearing partition, it is permissible to set the studding on a sole plate directly on top of the subflooring. If a 2 by 6-in. sole plate is used with 2 by 4-in. studs, and a 2 by 8-in. plate with 2 by 6-in. studs, and if this plate is accurately sized to a width 1½ in. greater than the stud width, it can be used as a ground for the partition plaster.

When a non-bearing partition is parallel with the direction of the joists, and there is no partition framing into the floor from above, a support must be provided at the top. The studs are capped with a piece of studding at such an elevation that the top of the cap is flush with the underside of the floor joists at either side of the partition as shown in Fig. *d*. Blocks, about 3 by 3 in., are then framed between the joists and nailed across the top of the cap, to hold the top of the partition in place. These cross-pieces should be spaced approximately every 3 ft. A nailing surface for ceiling lath can be provided by spiking pieces of board 3 in. wider than the partition cap along this cap between the cross-pieces.

Figures *a* and *b*, *Plate* 9, illustrate methods of framing the studs at partition corners; the one providing a nailing surface for the wood lath should be especially noted. The method shown in Fig. *a* is better than

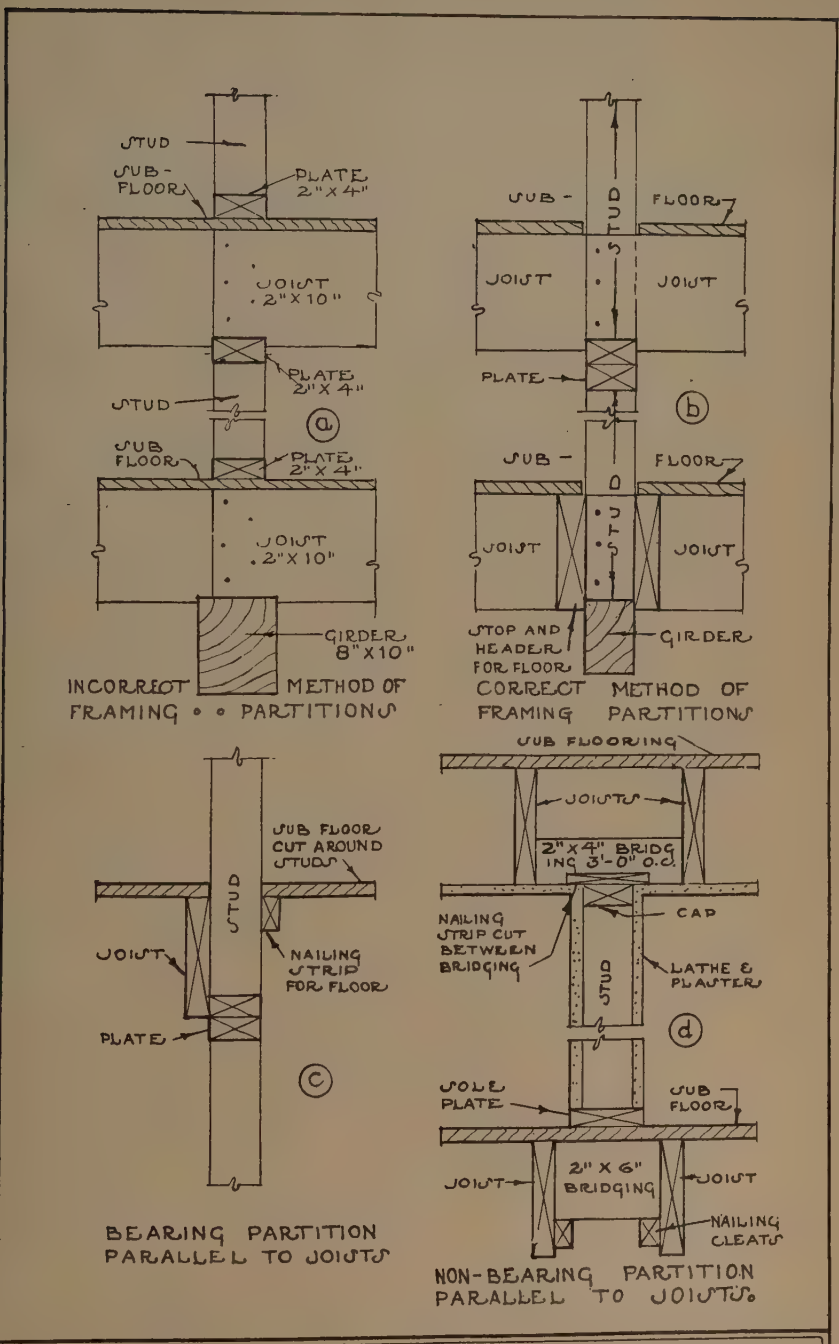

STUD
SUB-FLOOR
PLATE 2"X4"
JOIST 2"X10"
PLATE 2"X4"
STUD
(a)
SUB FLOOR
PLATE 2"X4"
JOIST 2"X10"
GIRDER 8"X10"
INCORRECT METHOD OF FRAMING PARTITIONS
SUB-FLOOR
STUD
JOIST
JOIST
PLATE
(b)
SUB-FLOOR
STUD
JOIST
JOIST
STOP AND HEADER FOR FLOOR
GIRDER
CORRECT METHOD OF FRAMING PARTITIONS
SUB FLOOR CUT AROUND STUDS
STUD
JOIST
NAILING STRIP FOR FLOOR
PLATE
(c)
BEARING PARTITION PARALLEL TO JOISTS
SUB FLOORING
JOISTS
2"X4" BRIDGING 3'-0" O.C.
CAP
NAILING STRIP CUT BETWEEN BRIDGING
STUD
LATHE & PLASTER
(d)
SOLE PLATE
SUB FLOOR
JOIST
2"X6" BRIDGING
JOIST
NAILING CLEATS
NON-BEARING PARTITION PARALLEL TO JOISTS
PARTITION • CONSTRUCTION

Plate 8.

that shown in Fig. *b*. A still better way in high-class work is to use a solid 4 by 6-in. as in Fig. *c*, or even a 4 by 8-in. post, instead of the two parallel studs shown in Fig. *a*, or else two 2 by 6-in. studs, as in Fig. *d*.

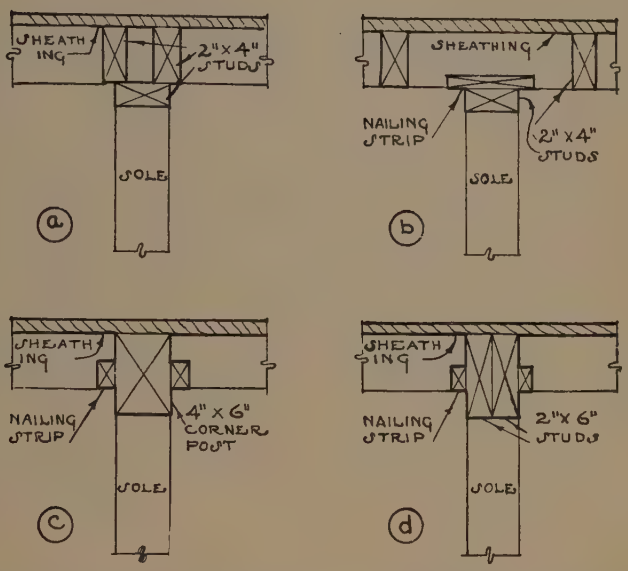
Lathing should never extend through the end of a partition, as this would cause a plane of weakness in the wall. Occasionally, it will be necessary to run a partition parallel with the direction of the joists and over a room of such width that sagging in the partition might be expected. This should be overcome by trussing the partition, as indicated in Fig. *e*. The size of diagonal bracing tie-rods and washers depends upon the span, dead load, and any loading that may come down from the floor above. The truss, of course, must have ample bearing and supports. A partition of this kind should be slightly crowned, since the truss is likely to settle a little after the lumber is seasoned. Trussing will not prevent settlement from shrinkage, unless the bottom member of the truss is thoroughly seasoned.

LATH

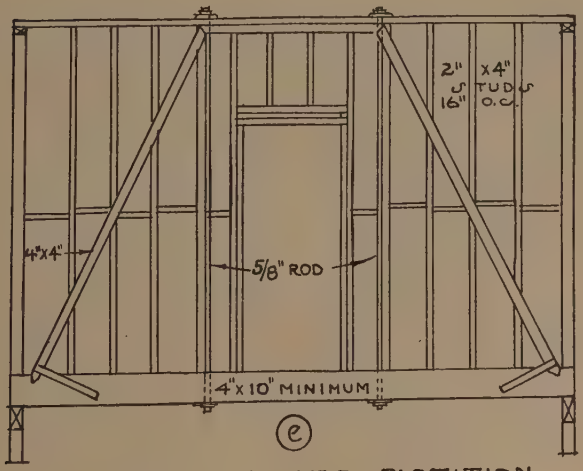
Lath is a material which is designed to act as a base to which plaster is applied. It is fastened to the studs or masonry either directly or by means of furring strips and is so made that the plaster will firmly adhere to it. Probably the most important function of wood lath is to hold the scratch coat of plaster in position until it has had time to harden. It must also display sufficient rigidity to prevent the "key," or mechanical bond of the scratch coat, from breaking when the brown coat is applied. Finally, it acts as a reenforcing material, to distribute any strains which may come upon the hardened plaster, thus reducing the tendency to crack.

The occupant of a building is continuously cognizant of the quality of the plaster on the walls and ceilings. Daily impressions, made perhaps unconsciously upon his mind, compel him to become aware of whatever faults or excellencies it may possess. To him its obvious value is decorative; and, though it has other functions, it is important to apply the wood lath so that disfiguring plaster cracks will be reduced to a minimum.

The value of wood lath depends chiefly upon the kind of wood of which it is made and its dimensions. A wood lath, especially if it has a crooked grain, may warp or buckle when wet. If the laths are thoroughly soaked prior to use, the few bad ones in the shipment can readily be culled out; or the warping can be detected and repaired before the plastering is completed. It is usually desirable to specify that either No. 1 or No. 2 lath may be used. The purchase of No. 2 lath will probably necessitate the culling out of a greater number of unsatisfactory laths from a shipment, either because they warp out of shape when wet, or because they contain live knots, the resin from which may come through the plaster



VARIOUS METHODS OF FRAMING STUDS AT PARTITION CORNERS.



TYPICAL TRUSSED PARTITION

PARTITION • CONSTRUCTION •

Plate 9.

and discolor it. If the laths are not completely saturated when the plaster is applied, they will absorb water from the plaster and expand; and if the plaster hardens before this expansion is complete, it may shear the key, breaking the bond between the lath and the plaster. If the plaster does not harden until afterward, the subsequent drying and contraction of the lath will leave it loose in the plaster. The best way to reduce the amount of this expansion is to reduce the dimensions across the grain of the wood. It is, therefore, recommended that specifications require wood lath to be ¼ in. thick by 1½ in. wide, with permissible variations of 1/16 in. in thickness and ⅛ in. in width, plus or minus. Commercial lengths of wood lath are 32 or 48 in., with a permissible variation of ¼ in., minus only.

Lath on walls should be laid horizontally. In narrow panels they should not be placed at an angle to exceed 60 deg. from the horizontal. Lath on ceiling should run in one direction only. Joints should be broken at least every seven laths to prevent cracking of the plaster.

Laths should be spaced to give not less than a ⅜-in. key for mortar. and a full ¼-in. key for hard plaster. There should be a space of ¼ in. between abutting ends of laths.

All laths should be nailed to each stud, joist, furring, or other bearing which it crosses, with 3-d fine wire nails.

Unless the laths are quite green, they should be thoroughly wetted as late as practicable prior to the application of the plaster.

One manufacturer is now furnishing a "seven-in-one" wood lath panel, made up of seven laths, fastened together to form a panel by means of reinforcing strips which are spaced to come midway between the studding. Very appreciable savings are claimed for this product on account of the large reduction in the amount of labor used in applying it.

Supporting furring, joists, or other base for the attachment of wood lath should be spaced not more than 16 in. center to center. The face of a single supporting member should not exceed 4 in. in width. Where wider support is used, it should be offset from the face of the wall sufficiently to allow the application of a narrow furring strip. Supporting members should be arranged in true alignment and be made rigid, to provide a secure and permanent hold for nails. Such members should be solid at angles and corners, to prevent the extension of lath through the angles.

With the ordinary masonry wall of brick, stone, cement block, or poured concrete, plaster should be applied to lath nailed on furring strips fastened to the wall. At times, plaster is applied directly to the masonry, but in such cases the wall should be waterproofed, and even then condensation may cause defects in the plaster.

Perhaps the most important advantage in the use of furring and lath on masonry walls, however, lies in the reduced heat losses assured by the

dead air space, between the lath and the wall. Furring and lath on masonry walls are indicated in Figs. e and f, *Plate* 23.

Even here some experienced builders advocate waterproofing the wall because of the danger, first, of the plaster drippings blocking up the furring space and then of moisture penetrating the wall and by capillary action being conducted across to attack the plaster, particularly if a hard mortar is used.

Before any plaster is applied, all grounds should be in place; they should be at least ¾ in. thick. The thickness of grounds is important in view of the tendency to increase lath thickness and reduce the thickness of the ground and so use less and less plaster. Formerly, ¼-in.-thick lath, with 1-in. grounds, was the general rule. As a result, ¾ in. plaster was used. Nowadays, with ⅜-in. lath, and ¾-in. grounds or even less, the plaster is often only ⅜ in. thick, and when some of the ½-in. plaster boards are used, the plaster may be only ¼ in. thick, whereas at least ½ in. of plaster is recommended.

The installation of mechanical equipment for plumbing, heating, and wiring, should be carefully considered before construction is started. Proper provision in the arrangement of framing should be made for soil pipes, furnace pipes, etc., to avoid the unnecessary cutting of timbers.

Heating pipes should be kept clear of the woodwork to avoid fire hazard.

If the basement ceiling is not plastered, the area over the furnace should be protected by sheet metal or metal lath and plaster placed an inch from any wood surface.

PLASTER BOARDS, FIBER BOARDS AND WALL BOARDS

Wall boards is a name loosely given to the various types of boards such as plaster boards, pulp boards, fibrous insulating boards, and a composite board composed of a wood core covered with paper. As a substitute for lath and plaster these boards are sometimes used in permanent buildings for economy and also for temporary construction, partition work, in attic spaces, and for similar uses.

These boards may be classified in three groups: (1) that in which the material is intended to act as a substitute for lath, or, in other words, plaster boards; (2) the group in which the material is intended to serve in place of both lath and plaster, or wall boards; and (3) the loosely textured fiber boards designated by the trade as *insulating boards*.

Boards which serve as a plaster base are usually 32 by 36 in. and are ship-lapped and V jointed. In general, when such boards are used, studding should be, at most, on 16-in. centers. Headers should be framed between studs at all horizontal joints. They should be applied in accordance with manufacturers' directions.

The chief difficulty with these boards is the tendency to pull apart at the joints. Strips of various materials have been tried, and also staples, in an attempt to obtain a smooth base for the plaster. It is now generally recognized that a thick coat of plaster is necessary over boards used as bases, but even then the risk at the joints still exists.

Some of the rigid fiber wall boards, as distinguished from dense pulp boards, have valuable insulating properties, resisting heat loss from two to three times as efficiently as wood in equal thicknesses. Since such boards are seldom used in the same thickness as lumber, most of this advantage is lost. The principal uses of fiber boards are as a substitute material for wood sheathing, for lath, for lath and plaster, and for the insulation of attics and floors over unheated basements.

Another and more effective method of insulating frame construction against heat loss is by installing semirigid, flexible, or quilt insulating materials in the spaces between studs, rafters, or joists.

Wall Boards Used for Interior Finish.—In some of the speculative small houses now being built, low first cost is one of the chief aims, and, as a result, various wall boards are used in place of lath and plaster. Since these boards, however, do not present an unbroken surface, they must be covered at the joints with strips or joint fillers. One prominent New England housing corporation has overcome this difficulty by standardizing on an 8-ft. ceiling height. Wall board is purchased in lengths which are 4 ft. wide. Two widths are then needed to cover the walls. One 4 ft. piece is cut, however, to make one 16-in. and one 32-in. piece. The 32-in. piece is placed around the bottom of the room, with the 4-ft. piece above and, finally, the 16-in. piece at the top. The lower joint is then covered with a chair-rail molding, and the upper joint with a picture molding at a level with the top of the windows and doors.

It will be seen that in the method outlined above, all horizontal joints are covered with moldings, while the vertical joints are kept to a minimum or eliminated by using boards long enough to extend between the sides of openings, mantels, etc.

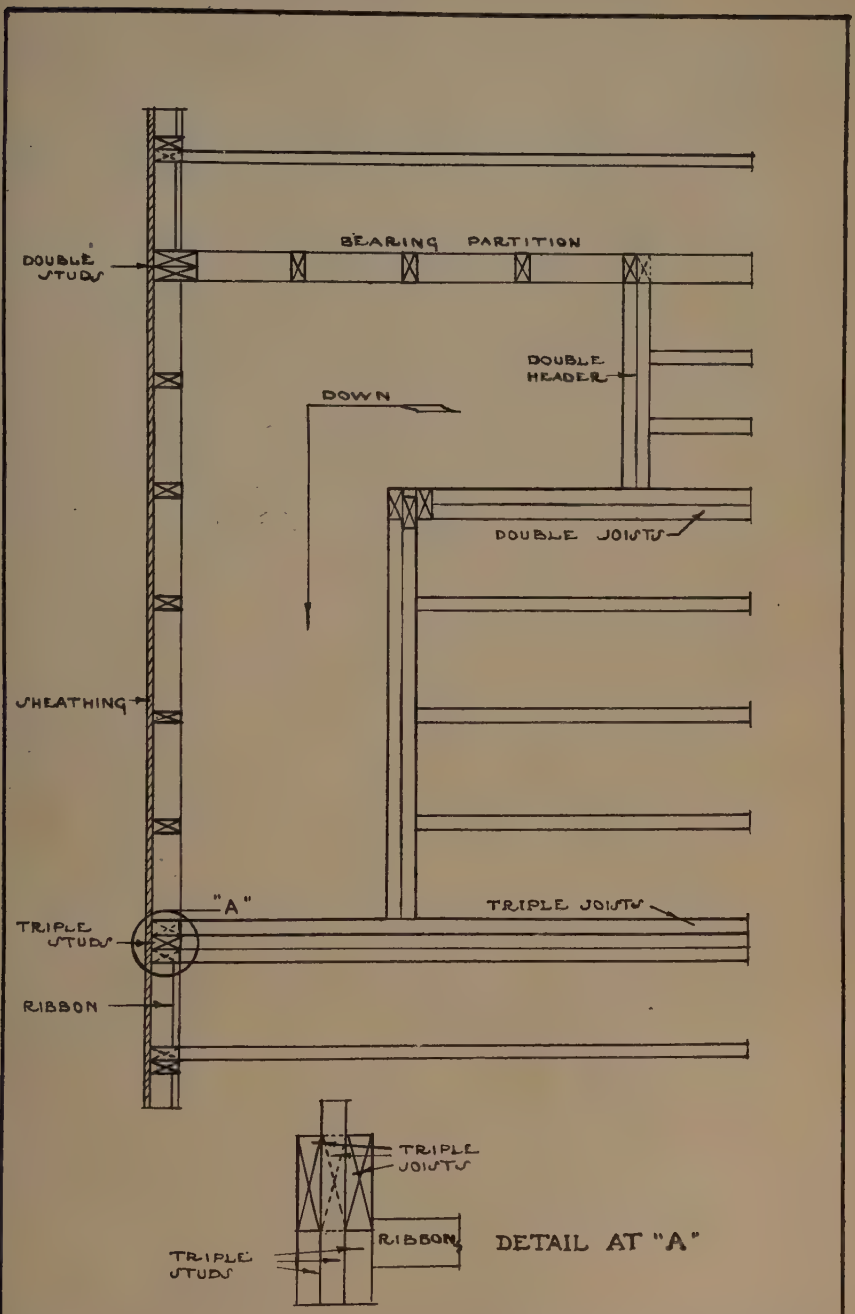
When moldings are not used over joints, fillers must be used, and even then the line of the joint may show through either painting or papering.

For bungalows, temporary partitions, and similar purposes, however, where a good finish is not needed, wall boards have a useful field.

STAIRWAYS

In order that the contractor may know what is expected, it is necessary to furnish ½ or ¾-in. scale drawings and to describe the construction of stairways, in the specifications.

When it becomes necessary to cut away one or more of the floor joists, as in case of an opening for a stairway, the strength lost in cutting these joists must be regained. Good practice calls for framing around the floor openings similar to that shown in *Plate* 10. The joists cut away for



FRAMING · AROUND · STAIR-WELL

Plate 10.

the opening are secured to a header made up of two pieces of lumber the same size as the joists. These headers are, in turn, supported by full-length joists either doubled or tripled, depending upon the amount of material necessary to carry the expected load. The framework around the opening is thus again tied together, and the joists which are cut away are properly supported. Where headers longer than 6 ft. are necessary, they should be fastened to their supporting joists by means of stirrup irons or joist hangers. *Plate* 10 brings out clearly the members to be reinforced and indicates the amount of joist material added.

In planning the stair layout, it is desirable to limit the sum of the rise and tread from 17½ to 18 in. Risers should never exceed 8 in. in height and should ordinarily be 7 or 7½ in. The tread should be approximately 10 in. from riser to riser for a 7-in. rise. Main stairs should be at least 3½ ft. wide. The detailed plan should show the number of risers, and the width of the stairways, besides indicating the details of the joist framing around the stair well.

The treads are usually not less than nominal 1¼ in. thick, and the risers nominal 1 in. thick; tongued and grooved so that they may be mortised and tenoned together at the building.

Stairs are of the *open* and *closed* types. In the former, the stringers are cut out and mitred, with the risers and the tread extended over the stringer in the same manner as at the riser. In the closed types, the stringer is a boxed one, with the inner stringer a combined structural and finished member, and the outer stringer a finished one to close in the rough structure of the stairs. The closed type is the stronger of the two.

The wall stringers of both types of stairs, and the inner stringer of the closed type, should be accurately cut out to receive the risers and treads; and from the underside, hardwood wedges should be driven up snugly and glued in place.

In stairs over 3 ft. wide, structural members, termed *carriages*, should be provided between the stringers and placed not less than 2 ft. apart. The carriages should be cut out to fit the underside of steps and secured to the floor and platform construction rigidly and wedged at the steps with hardwood wedges.

At floors and landings, the stringers should be well secured to the floor construction or to posts, preferably with screws. Where stringers are secured to posts or to one another, they should be fastened by special bolts, made for this purpose and so placed as to be concealed.

Platforms or landings between the floors should be framed to carry properly the weight of the stairs and the live load to be imposed upon them. The arrangement is dependent upon the detail or plan of the stairway.

The underside of the stairs should be closed in with plaster or material selected for the wall treatment. Provision for this should be made by

means of furred strips set 16 in. apart for wood lath or ribbed metal lath, and 12 in. apart for flat extended lath.

The balustrades or railings of the required or desired architectural design can be secured to the stringers by concealed fastenings. The rails should be held by special stair bolts fastened to the posts.

See Chap. IX for various details of approved stairway construction.

ROOF FRAMING

In all types of roof framing it is important to provide a sufficient pitch, which should be at least one-third, or a rise of 8 in. in 1 ft., in snow areas. Simple lines are best, as they eliminate valleys and hips, with their resultant joints and chances of leakage. The Red Cedar Shingle Bureau recommends a rise of 6 in. in 1 ft. for shingle roofs, which is equivalent to a one-fourth pitch.

Roof rafters must be of sufficient size and strength to support the weight of the roof, to carry a snow load, and to resist wind pressure without sagging. If the rafters are too far apart or of too great a span, they will sag and thus split and loosen the shingles, causing a leaky roof. The spacing, which will usually be limited by the local building code, should not be over 24 in. for a shingle roof; by using a 16-in. spacing, or other multiple of 48, the ceiling lath can be applied with a minimum of waste. When a greater spacing is used, it is generally necessary to strap the rafters in order to obtain a base for the lath and plaster.

The shed or lean-to roof is the simplest form and, as its name implies, is used for small sheds, porches, or minor buildings. It has only one slope.

The saw-tooth roof is a development of the shed or lean-to roof and is essentially a series of lean-to roofs covering one building. It is used mainly in industrial buildings, because of the extra light which may be obtained through windows on the vertical sides thus formed.

The gable or pitched roof is, of course, very commonly used. It is a simple and efficient form of roof and is extensively applied to farm buildings and small houses. It is of triangular section, having two slopes meeting at the center or ridge and forming a gable, as shown in Fig. *a*, *Plate* 11. It is popular on account of its economy and easy construction.

The span of a lean-to roof is usually limited to 8 or 10 ft., depending, of course, upon the size of rafters used. For spans up to 16 ft., simple gabled roofs, consisting of pairs of rafters resting on and fastened to plates on the studding and pitched upward to butt against and support each other at the ridge may be used. A ridgepole running the length of the roof should always be used between the tops of rafters, so that they cannot slip past each other; this is shown in *Plate* 12, which also shows methods of framing in two common types of roof.

A collar beam or tie one-third of the way or one-half way down the rafter is often used with gabled roofs to hold each pair of rafters together.

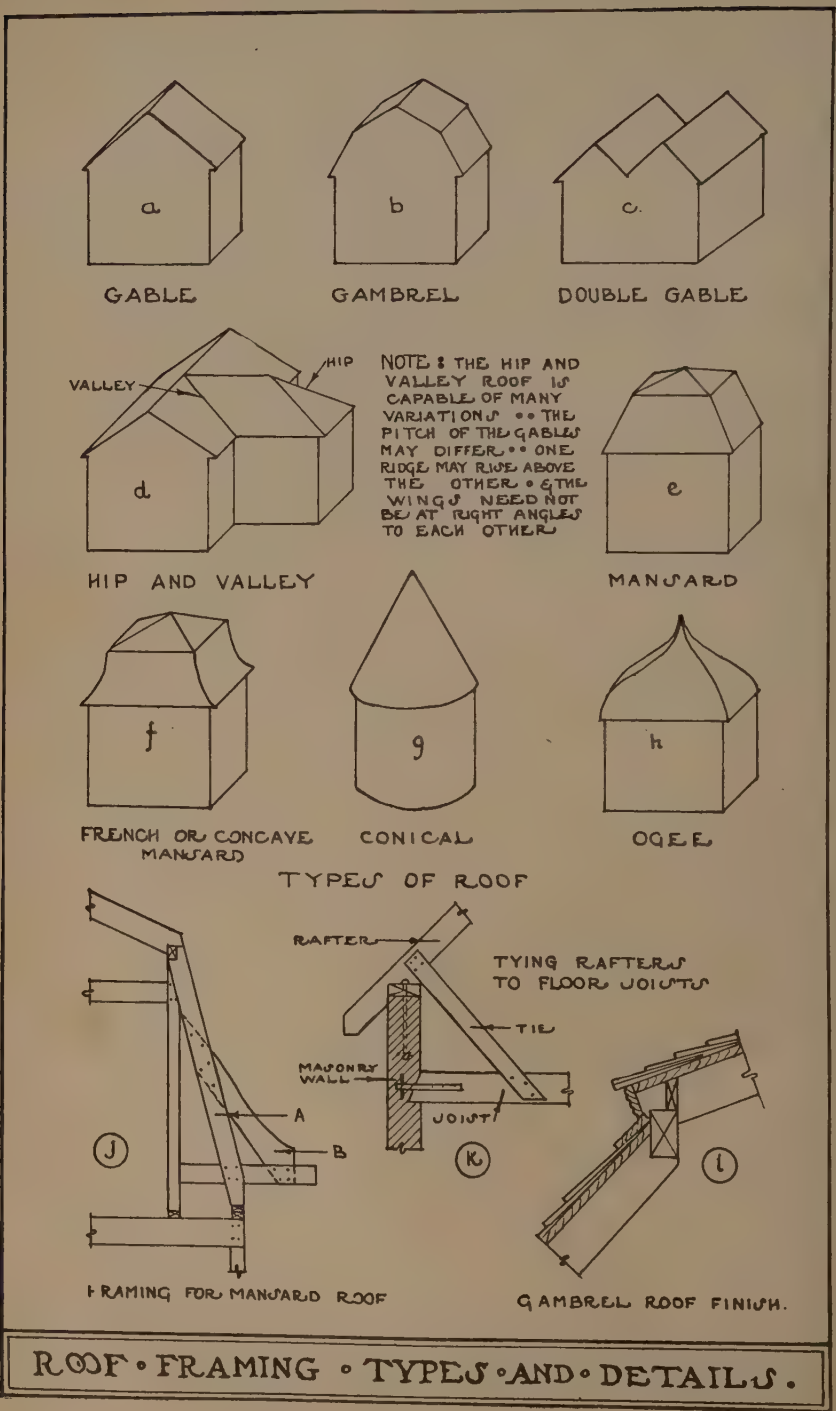
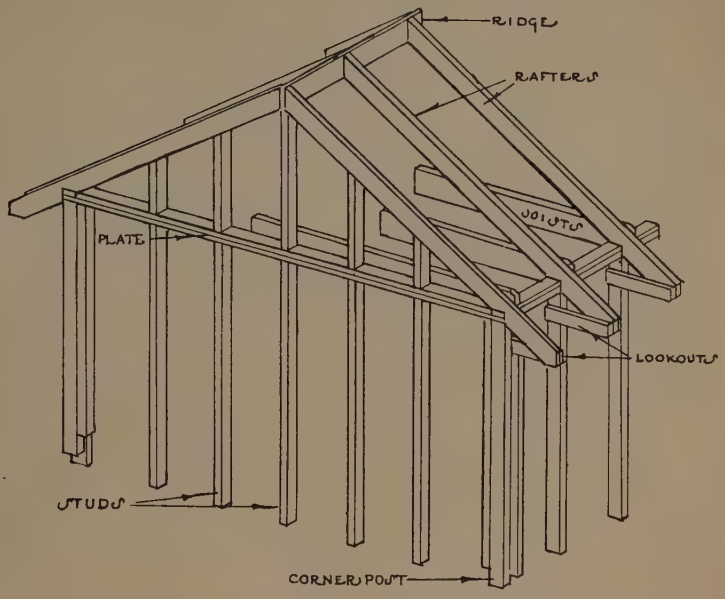
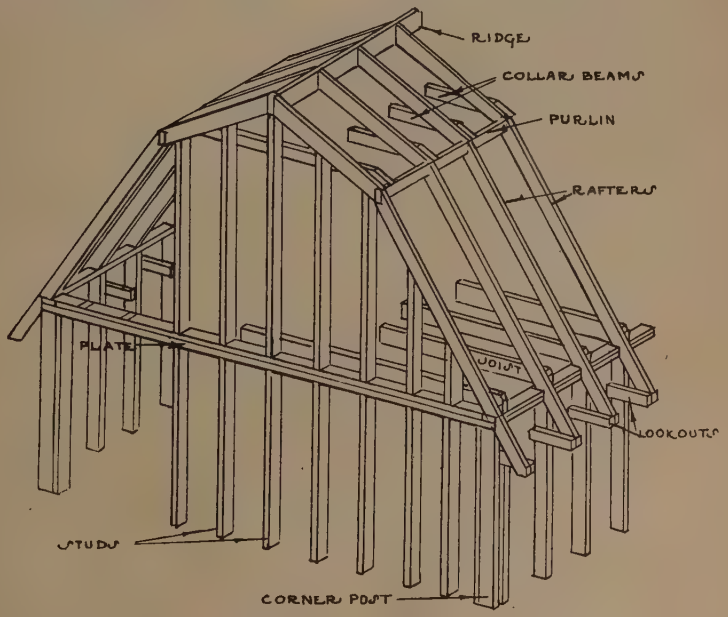

a
b
c
GABLE
GAMBREL
DOUBLE GABLE
HIP
VALLEY
d
HIP AND VALLEY
NOTE: THE HIP AND VALLEY ROOF IS CAPABLE OF MANY VARIATIONS .. THE PITCH OF THE GABLES MAY DIFFER .. ONE RIDGE MAY RISE ABOVE THE OTHER . & THE WINGS NEED NOT BE AT RIGHT ANGLES TO EACH OTHER
e
MANSARD
f
FRENCH OR CONCAVE MANSARD
g
CONICAL
h
OGEE
TYPES OF ROOF
RAFTER
TIE
MASONRY WALL
JOIST
A
B
J
K
TYING RAFTERS TO FLOOR JOISTS
l
FRAMING FOR MANSARD ROOF
GAMBREL ROOF FINISH.
ROOF . FRAMING . TYPES . AND . DETAILS .

Plate 11.



GABLE ROOF CONSTRUCTION



GAMBREL ROOF CONSTRUCTION.

• ROOF • CONSTRUCTION •

Plate 12.

With the roof spans short, collar beams may be omitted, though it is usually better practice to use them, regardless of the span of the roof. Collar beams prevent the rafters from sagging, and, if the attic is to be finished, serve also as ceiling beams. Care must be taken to insure that they are securely nailed to the rafters. Another method of stiffening the rafters, where clearance is unimportant, is to tie the lower ends of each pair of opposite rafters together. This forms a triangular truss called a *closed-couple roof*, and these collar ties or beams, besides preventing the rafters from spreading, take up the roof thrust on the side walls.

A common method of furnishing stability to the roof framing is to run two pieces of 2 by 4-in. lumber the entire length of the roof, 5 or 6 ft. up from the eaves, with a line of studding underneath to support these pieces at least at every sixth rafter. When there is to be a finished attic in the building, these studs may be used to form the side walls of rooms. In this event, the uprights must be spaced on 16-in. centers to receive the wood lath.

The hip roof is formed of four straight sides sloping toward the center of the building, terminating in a ridge. The pyramid roof is a modification of the hip roof, in which the four straight sides sloping toward the center terminate in a point instead of a ridge.

The hip-and-valley roof, as shown in Fig. *d*, *Plate* 11 gets its name because hip-and-valley rafters are required in its construction. There are many modifications of this roof.

The double-gable roof is a modification of a gable or a hip-and-valley roof in which the extension has two gables, forming at its end an M shape, as shown in Fig. *c*.

The ogee roof has a pyramidal form with steep sides sloping to the center, each side being ogee shaped, that is, lying in a compound hollow and round curve, as shown in Fig. *h*.

The conical roof, or spire, is a steep roof of circular section which tapers uniformly, forming a circular base to a central point, as shown in Fig. *g*.

The gambrel roof was probably developed from the simple gable by breaking the roof surface near the middle on either side of the building. The portion of the roof below the break was made steeper, while that portion above the break was flattened out. The gambrel roof has a kind of gable at each end of the building.

Figure *i* shows the finishing details at the middle joint of a gambrel roof, with a different framing from that illustrated in *Plate* 12. A good feature of this particular detail is the use of a finishing strip, or fascia, and the overhanging of the shingles on the upper roof surface, so that water dripping off will fall clear to the lower roof surface and not soak under the shingles and ends of upper roof rafters and cause them to rot.

The mansard roof, although somewhat similar to the gambrel roof, slopes from each wall toward the center instead of from only two opposite walls, as is the case of the gambrel roof. The surface sloping up from each wall plate is nearly vertical, and as a result the upper surface is quite flat. Figure *e* shows this type of roof.

Figure *j* shows a framing detail for mansard roof. It should be noted that the piece *A*, resting on the plate, should always be a straight piece of lumber; and if a curved effect is wanted, it should be secured by adding a small furring piece *B*, which is nailed to the horizontal lookout and also to the inclined roof member *A*.

The French or concave mansard roof is a modification of the mansard roof, its sides being concave instead of straight; it is illustrated by Fig. *f*.

The gambrel and mansard roofs, both of which bring smaller thrusts on the side walls, offer another solution to the problem of obtaining greater attic space, although frequently they are used simply to secure a different architectural effect.

FRAMING RAFTERS TO SIDE WALLS

The method of framing rafters to side walls depends chiefly on the clearance desired in the attic. When attic space is not important, the simplest and probably the commonest method of framing rafters and ceiling joists over the wall plate, is that illustrated in *Plate* 12.

When headroom in an attic is desired near the eaves, it is customary to extend the wall studding up above the attic floor level, to the height desired. The attic floor joists are then framed over ledger boards and nailed to the studs, as in ordinary balloon construction. The studs are kept at the desired distance above the attic floor level, and the roof rafters are notched over the stud cap or wall plate, as before. This is shown in Fig. *k*, *Plate* 11; it may also be noted that a diagonal tie is shown running from the rafter to the floor joist. This is a particularly desirable feature in a house built with masonry side walls and is also desirable in ordinary frame construction. It braces the side wall above the attic floor and assists in taking the horizontal component of the rafter thrust.

On account of this thrust in rafters having a comparatively flat slope, it is good practice to notch the rafters deep enough over the wall plate so that they will have a bearing surface against the inner face of the plate rather than simply on top of it.

ROOF COVERINGS

The roof boarding over the rafters consists of either a solid deck of sheathing or an open deck of roof laths covered by wooden shingles, or other roofing material. For slate, tile, and other heavy roofings, wood sheathing is generally used as a base. Tongued-and-grooved boards are

preferable, although square-edge, rough boards not more than 8 in. wide, and also ship-lap boards, are favored by some builders.

The use of roof lath or nailing strips, 1 in. thick by 2 or 3 in. wide in place of a solid deck, is prevalent in certain localities but, on account of lack of insulation, is not to be recommended for the better class of buildings, except in warm climates. Although most authorities favor the use of such nailing strips as a base for wooden shingles on account of the thorough ventilation thus provided, no recorded experience or other data have been found to indicate that such strips have any advantage, from a decay-retardant standpoint, over a solid sheathing.

In many sections of the country, the use of nailing strips is common practice. In certain Northern states, however, notably in Michigan, the solid deck is much preferred and is extensively employed as a shingle base. This may, of course, be partly due to the necessity of providing greater insulation against a rigorous climate, but, if the solid deck does afford sufficient ventilation to check any possible decay in a shingled roof, its use should be strongly recommended for two reasons: first, the high insulating qualities already mentioned; and second, the increased fire resistance, estimated at approximately 15 minutes.

The main function of a roof covering is to keep out the elements, without increasing the fire hazard from chimney sparks or flying brands. A thick edge-grained, wooden shingle performs this function economically when it is properly nailed.

The selection of roof covering depends upon a number of considerations; but, other things being equal, the architect usually prefers the wood shingle. He knows that good shingles are easily handled and, when properly nailed, will outlive most other ordinary forms of roofing.

In the early days, wooden shingles were rived from blocks of wood and were known as *shakes*. They were rough and of the same thickness at both ends. An improvement was the shaved shake or shingle, the shake being so shaved with a drawknife that it was thicker at one end than at the other.

Shingles today are manufactured by means of shingle saws which in some of the larger mills produce anywhere from 100,000 to 250,000 shingles a day. The species of wood used are mainly western red cedar, redwood, and cypress, although in many sections eastern white cedar, white pine, southern pine, and sugar pine find a rather extensive local use.

It is the inexperienced and unscrupulous builder who has brought the wooden-shingle roof into disrepute, not only by using inferior grades of shingles but also by putting them on with steel nails.

The nail is really the critical factor in the structural stability of the shingle roof. Copper or zinc-coated, hot-dipped cut iron nails are best, though galvanized nails, used with the proper kind of shingles, will give good results. No one would intentionally use a 40-year shingle with a

5- or 10-year nail; but lack of attention given to the kind of nail used in laying shingles frequently has caused losses to home builders which are the equivalent of losses that would result from such action.

The popularity of the common wire nail is, of course, easy to explain. It is cheap, and there are more nails to the pound than in the case of other nails. But the wire nail rusts, and the shingles loosen long before they wear out. In fact, poor shingles with good nails make better roofs than good shingles with poor nails.

The following specifications will assure a tight, durable roof:

1. Use edge-grain shingles, measuring not less than five shingles to 2 in. in thickness, measured at the butts or thick ends. (In edge-grain shingles the annual rings show as approximately vertical lines in the end section). Shingles are made in 16-, 18-, and 24-in. lengths. The 18 and 24-in. shingles can be laid safely with larger weather exposure and can be laid more rapidly. All shingles over 9 in. wide should be split before laying. Sixteen-inch shingles on a roof having a one-half pitch or greater, should be laid 4½ in. to the weather; 18- to 24-in. shingles can be laid safely with greater exposure.

2. If shingles are not to be stained, soak them thoroughly in water before applying. If stain is to be used, dip the dry shingles two-thirds their length in stain, and dry again in a loose pile. Do not soak them in the stain. To secure uniform color, add a second coat of stain after laying. Cheap stains, especially those mixed with kerosene or benzine should not be used. A reliable creosote stain is best.

3. Lay the first course two ply, allowing from 1¼ to 2 in. projection over crown mold, and 1 in. projection at gables. If shingles are not stained or thoroughly wet, space ⅛ in. Do not drive the heads of the nails into the shingles. Break joints not closer than 1¼ in., side lap.

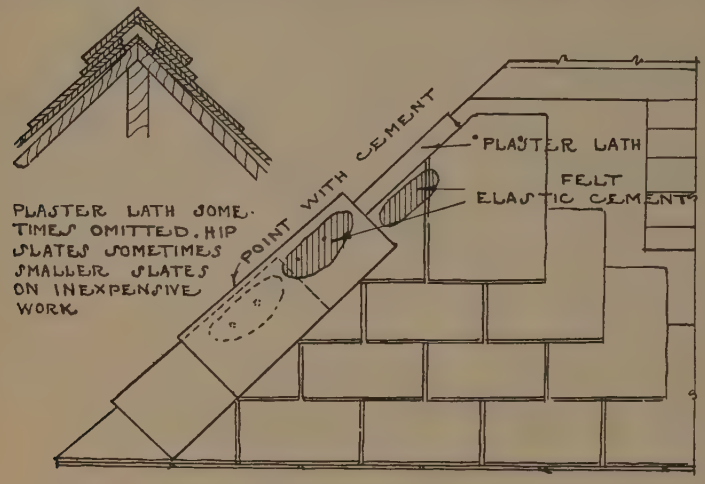
See that breaks do not come directly over each other on any three consecutive courses.

Much trouble will be avoided when shingles are carried out over a molding if they are bedded in a mastic cement or similar material.

Hips may be finished in several ways. Figures 74 *a* and *b* show the details of a *saddle hip* and of a *mitred hip* recommended by the National Slate Association. Shingle roofs may be finished similarly. Another popular type of hip is known as the *Boston hip*, in which the shingles or slates are laid over the regular courses on either side of the hip, in rows of even width.

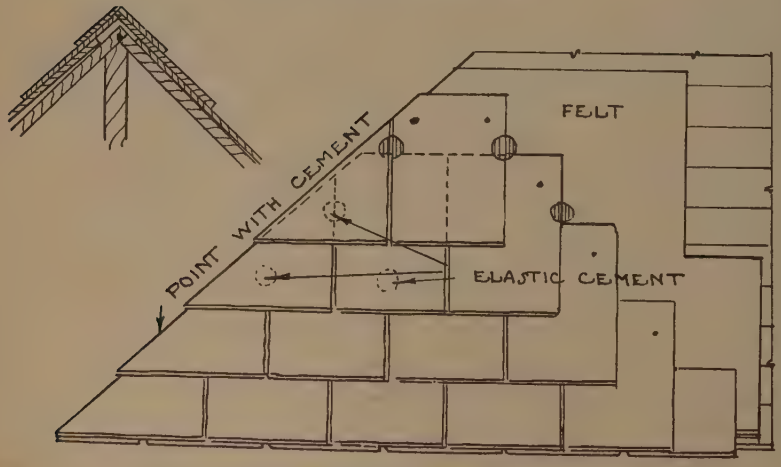
Valleys may be formed as either open valleys or closed valleys. The former method, undoubtedly the better from a construction standpoint, consists of laying strips of sheet metal in the valley angle to form a channel for water draining off and then lapping the shingles or other roofing material over the edges of the sheet metal.

In the closed valley, the roofing material entirely covers the sheet-metal flashing in the valley and fits together at the valley line. The



SADDLE HIP

FIG. 74*a*.—Hip finishing detail.



MITRED HIP

FIG. 74*b*.—Hip finishing detail.

flashing sheets may be placed between the slates or shingles, as shown in *Plate* 24, page 328.

SHEATHING

Since sheathing is placed over the studs mainly for warmth, its chief function is that of a covering material. Low-grade lumber dressed on one side and not over 8 in. wide is generally used, but short-length, end-

matched boards are coming into favor (see p. 300). A good grade of building paper, placed between the sheathing and the siding, is essential, for it makes the building practically air and moisture proof, especially if the openings are properly sealed.

Sheathing boards should be laid tight and properly nailed to each stud with not less than two 8-d. nails, and where exterior walls or parts thereof more than one story high are sheathed, the boards should be not less than 1 in. nominal thickness.

Although the question as to whether sheathing should be laid horizontally or diagonally cannot be categorically answered, it is believed that preference should be given to the diagonal method, except when a stucco finish is to be applied.

Diagonal sheathing[1] furnishes an extremely stiff bracing to the walls of a building. In fact, it is claimed that a single sheathing board, run diagonally from corner to corner of a wall and thoroughly nailed to all of the studs with two 8-d. nails in each stud, will make a more rigid wall than the entire side covered with partially dry horizontal sheathing, nailed in the same manner as the diagonal plank.

When a building is properly braced, however, with corner braces at each floor level, there is no doubt that it will have sufficient stiffness, whether the sheathing is applied diagonally or horizontally. The point is that some kind of diagonal support, whether it be corner bracing or diagonal sheathing, should be provided. The platform type of house might be an exception to this, however, as only diagonal bracing would seem to provide proper bracing to tie the upper and lower stories together.

Another claim for the superiority of the diagonal sheathing lies in the fact that the joints in the sheathing will not parallel those in the siding. With horizontal sheathing, any marked variation in the thickness of the rough boards might show up in the finished covering; whereas the diagonal sheathing would bridge over such an unevenness and conceal it.

When a building is to be finished with stucco, wooden sheathing laid horizontally is less apt to result in stucco cracks than when it is laid diagonally. This conclusion is the result of a comprehensive series of tests on full-sized panels constructed and tested at the Bureau of Standards over a period of several years, to determine the best method of attaching portland-cement stucco to wood-frame construction to avoid the development of cracks. A series of more than 30 panels was built and allowed to weather for a complete cycle of the seasons, and careful observations and measurements were made to determine the character and extent of cracking that developed in the variously constructed panels. The couple of force developed by the two nails which attached each diagonal sheathing board to the studding, when the sheathing shrunk in a

[1] Recently completed tests at the Forest Products Laboratory indicate that diagonal sheathing with 2 nails at each stud has 4 times the resistance of horizontal sheathing with 2 nails and 6 times the resistance if 3 nails are used.

direction perpendicular to the main axis of the board, apparently had a disturbing effect upon the stuccoed surface and caused more cracking than resulted when horizontally applied sheathing was used; for in the latter case the shrinkage of the board was in the same direction as the line of the stud to which the board was nailed, and no disturbing force couple was developed by the nails.

SUBFLOORING

Subflooring should be used in all first-class work. Its use is distinctly worthwhile in all except temporary buildings. The saving in omitting the underfloor is usually very slight, while the benefits of having it are considerable. In the first place, a subfloor, especially if laid diagonally, greatly stiffens the building during construction and not only is a great convenience to the workmen but also allows the laying of the finished floor to be deferred until the building is nearly finished.

The same kind of material that is used for sheathing is suitable for subflooring purposes, except that a somewhat higher grade is usually desirable. If a No. 3 common grade is used for sheathing, a No. 2 common grade should be used for subflooring.

Lumber used for subflooring should be dressed one side, and the narrower the boards are, the better. The best way to lay subflooring is on an angle of 45 deg. with the length of the joists, being careful to cut the boards around the studding. If the direction of the subflooring on the first and second floors is reversed, a certain stiffening effect is added to the structure. Besides adding stiffness to the frame, diagonal subflooring insures a smooth surface to the finished floor and permits it to be laid in either direction.

There is likely to be a slight unevenness of surface in any subflooring; but if the underfloor is laid diagonally, this slight unevenness is eliminated by laying the finished flooring either parallel to the joists or across them. But if the subflooring is laid straight across the joists instead of diagonally, the finished flooring must be laid crosswise to the subflooring, or else it will reproduce any unevenness that may exist in the undersurface.

In many of the architectural offices, it is now standard practice to continue the subflooring to the outside line of the studding. This affords both a fire stop and a weather stop.

FINISHED FLOORING

The finished floor should never be laid until the plastering is all done and thoroughly dry; in fact, it should be the very last part of the building to be completed. All baseboards, casing, and door hangings should be installed before the finished floor is laid.

Where cost is secondary, hardwood such as maple, birch, beech, and oak are used. Southern pine, Douglas fir, and other so-called *softwoods* are also used. Both these species are now obtainable in end-matched lumber.

Finished flooring should be laid across the subflooring, and a layer of deadening felt between the subfloor and the finished floor should always be provided. Shrinkage cracks at the corners of floors and walls can be avoided by keeping the finished floor away from the plastered wall the thickness of the baseboard and keeping the bottom of the baseboard flush with the top of the finished floor level, as shown in Fig. 75. The base molding is then held snugly against the joint by nailing it to the subfloor through the crack. The shrinkage of the floor, or baseboard, when this connection is used, will not pull the molding away from either.

In the cheaper class of dwelling, frequently only the living-room floor is finished with hardwood flooring.

In laying this flooring, it is essential that proper nails be used, to avoid splitting the tongue and bruising the face. The following practices are recommended to give the best results:

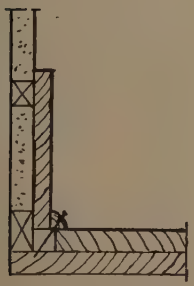


Fig. 75. — Approved method of nailing base molding.

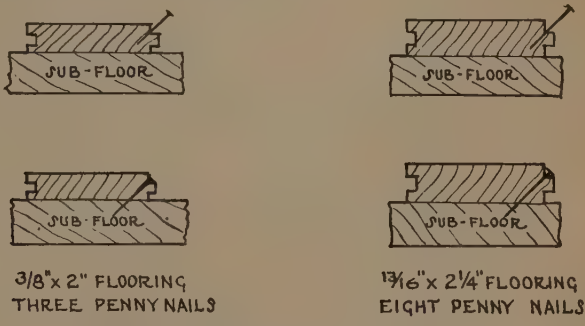


Fig. 76.—Showing initial and final position of three-penny finishing nails and eight-penny cut flooring nails.

Use 3-d. finishing nails 9 in. apart, for $\frac{3}{8}$-in.-thick flooring; use 8-d. cut flooring nails 16 in. apart, for $1\frac{3}{16}$-in.-thick flooring; and use 10-d. cut flooring nails 16 in. apart for $1\frac{1}{16}$-in.-thick flooring.

The 3-d. nail is a wire nail and is adapted to thin flooring on account of its small gage and medium length. The 8- and 10-d. flooring nails are steel cut nails, manufactured especially for laying hardwood flooring, and are used almost exclusively by up-to-date contractors and floor layers. These nails are the same thickness from point to head. They have two smooth sides which are set parallel to the tongue, eliminating the strain from the narrow part of the tongue. They are wedge shaped in width, which puts the entire strain lengthwise of the tongue. The rough edges give these nails drawing and holding qualities not possessed by any other nail, and after being driven their entire length they remain in position, producing and maintaining a perfectly tight joint.

The nail should be driven at an angle of 45 or 60 deg., and the first nails driven in the piece of flooring should be toe-nailed toward the preceding piece to which it joins. Figure 76 shows the 3-d. finishing nail

in the position it should take in starting; also, the same nail after being driven its entire length and set. It also shows the 8-d. cut flooring nail in the position it should take in starting; and the same nail after being driven its entire length and set.

SHORT-LENGTH AND END-MATCHED LUMBER

The use of short-length lumber in light building construction offers a real opportunity for economy in the price of lumber. By short-length lumber is meant lumber less than 8 ft. long. Pieces of wood 6 and 7 ft. long form part of the standard output of practically every sawmill and planing mill, and lengths of 4 and 5 ft. are also quite generally produced in the effort the lumber manufacturer makes to furnish standard lengths. It is the general practice of mills throughout the country to quote short lengths at from 15 to 35 per cent below the prices asked for lumber 8 ft. and longer. Exhaustive study has shown that it is possible to use as

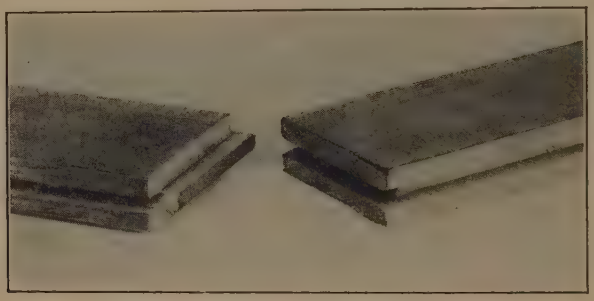


FIG. 77.—End-matched softwood lumber.

much as 20 per cent of the framing lumber that goes into the typical American small house in lengths of less than 8 ft. Only about 1.5 per cent of such lumber is at present being purchased from the mills. A wider demand, therefore, for lumber less than 8 ft. long will result in a definite saving in the cost of lumber to the consumer.

Boards for subflooring and wall and roof sheathing offer an excellent opportunity for the use of short-length lumber, particularly when the lumber is end matched. For a number of years past, hardwood-finished flooring has been furnished in end-matched pattern; that is to say, each piece, besides having a tongue along one edge and a groove along the other, has carried a tongue on one end and a groove on the other end, as shown in Fig. 77. The adaptation of the principle to lumber used for covering purposes in light building construction permits some marked economies.

Experience has already shown that where end-matched lumber can properly be used, a saving of from 10 to 25 per cent of the cost of other lumber can be effected. End-matched lumber is becoming quite gener-

ally available. It has several advantages, the chief one probably being that it can run along in ribbon fashion regardless of the position of supports. No attention need be paid to the location of joints. It is unnecessary to have joints over supports, and when the end of a run is reached the short piece that is sawed off can be used to start the next run. End-matched lumber can be laid with a minimum of sawing and other labor and with almost no waste material and affords another opportunity for the use of a large amount of short-length lumber.

End-matched wall sheathing is especially convenient for diagonal application, as the wall openings can be blocked out with little waste and lessened labor. Also, since end-matched joints need not be nailed to supports, length standards are unimportant, and clear boards may be sawed from knotty lumber, merely by cutting out the defects—a special advantage in using heartwood, where knots chiefly occur.

Recently, end matching as a manufacturing principle has been introduced on softwood drop siding, ceiling, and partition; and while these patterns have not been so thoroughly tested in actual use as has hardwood flooring, the advantages and economies in end matching will doubtless be established in these items as well as in subflooring and sheathing.

BUILDING PAPERS

In order that wood-framed buildings may be both wind and moisture proof, some kind of impervious lining should be placed over the sheathing and covered with clapboards, shingles, or other finished material. Various kinds of sheathing or building papers may be used for this lining. Since the primary function of such papers is to prevent or minimize the infiltration of air, resistance to air permeability is all-important; but building papers should also be tough and strong, so that they can be subjected to ordinary handling without tearing.

As a result of some recent tests on various papers, the Bureau of Standards has found that saturated papers are less permeable by air than unsaturated, those saturated with paraffin showing the least permeability. The Bureau finds that more extensive tests on actual walls, having the different kinds of papers built into them, will be necessary to obtain significant results and comparisons but that it seems doubtful if the differences in air permeability represent any appreciable differences in heating costs.

The papers were also weighed and measured, tested for strength, wet and dry, and for water resistance. Those papers saturated with tar or asphalt showed the greatest water resistance, but, as pointed out in the Bureau's report, aging properties, resistance to ravaging insects and rodents, and elastic properties may be found to have more significance than air or water permeability.

Meanwhile, it would seem to be sound judgment to take precaution to line the outside walls with a tough building paper which is not only air resistant but also water resistant, since moisture may find its way into a wall in even the best construction.

Building papers are almost always used under shingles, slate, or metal roofing. An asbestos sheathing paper with fireproof qualities is also used, at times. Some of the mineral wools and sheathing quilt (made of eelgrass), in addition to their better known insulation and sound-deadening qualities, are also fire resistant and are frequently used as lining between the subflooring and finished flooring. Felt papers, some of which are fireproofed, are also used as floor linings and wall linings. Probably the most commonly used of all linings are the cheap resin-sized papers, which are not waterproof but do serve to keep out dust and dirt and a great deal of wind. They should not be recommended for first-class work, except as a protection to flooring during construction.

Building paper should be applied just previous to the placing of the outside finish, or flooring, or roofing material. On walls and roofs it should be laid horizontally, with a lap of at least 2 in.; it should be laid over the paper already placed around door frames and windows to prevent wind's forcing its way through construction joints, weight boxes, etc. Figure 73 shows the proper application of building paper around a window.

All building papers, felts, quilts, and similar materials should be applied in accordance with the manufacturer's recommendation.

COVERING FOR OUTSIDE WALLS

Over the sheathing used to cover the studding in frame buildings, some sort of finishing surface must be provided. This surface usually consists of clapboards, siding, or shingles, depending somewhat on the locality, the construction cost, and the architectural effect desired. Shingles are more expensive than siding but have this advantage, that in using them a great variety of effects may be obtained. Shingles, moreover, are particularly susceptible to the absorption of stains and creosoting oils, the use of which not only provides a variety of effect but also insures long life to the shingles.

Shingles may be applied with a varying exposure to the weather, depending on the length of shingle used. As a result, two and sometimes three layers of protection are afforded, thus providing greater protection from the weather than when ordinary siding is used.

The kind of material used for this outside wall covering depends largely on the locality of the building, but, in any case, one of the more durable woods should be used. For shingles, western red cedar, cypress, or redwood can be employed with advantage. For the siding and clapboards these same woods are also extensively used, although white pine

or spruce, and sometimes hemlock or fir, are used with satisfaction in different sections.

No matter what form of outside wall covering is used, a heavy grade of tough building paper should be inserted between the sheathing and the siding, or shingle covering. Experiments conducted by the Bureau of Standards show that if a frame building is properly constructed, insulated with building paper carried over all joints at window and door openings, and protected with metal weather stripping at openings, it will be practically weatherproof.

A water table is the lowest part of the outside finish and is placed just above the top of the masonry foundation wall, in order to divert water running down the side of the building from the joint between the masonry and the sill. There are many different ways of constructing a water table, depending on the character of the building; two approved and fairly simple styles are shown in Figs. *b* and *c*, *Plate* 13. In Fig. *a* is shown a water table suitable for either siding or shingle finish. Note flashing details in this figure. It is apparent that both of these styles throw water well away from the foundation wall joint. On cheap work the water table is sometimes omitted; but the omission is almost sure to allow water to work its way in under the sill and cause dampness in the basement and decay in the sill.

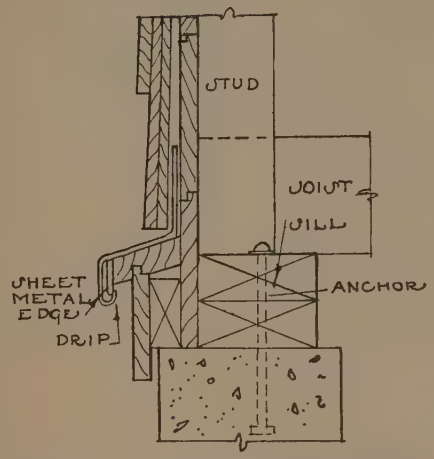
Methods of finishing the corners of a building on which siding is used are shown in Figs. *d* and *e*. Still another method is simply to mitre the siding to fit together at the corner as in Fig. *f*.

PREPARATION FOR STUCCO

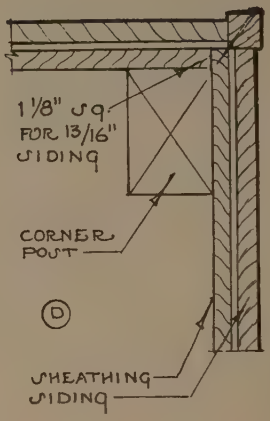
Stucco construction is a field of considerable importance, because approximately 90 per cent of the stucco-constructed buildings are of frame exterior walls. Many stucco experts prefer the framed backing to masonry, because, if properly done, there is no question about its holding up. It is important, therefore, to know what precautions should be taken to insure stucco wall construction that will give satisfaction as long as the frame building endures.

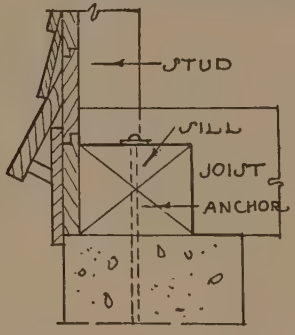
In the use of stucco, there are four fundamental factors which must be taken into consideration: (1) The building must be properly designed and constructed for stucco; (2) the material must be applied to a suitable base; (3) the mortar must be properly proportioned, and carefully mixed, from good materials; and (4) it must be applied by workmen having a knowledge of the material and skilled in its application, since workmanship cannot be written into specifications.

In the design of a new building or the remodeling of an old one for the application of stucco, the designer should so detail the construction as to prevent a concentrated flow of water over the face of the walls. This can generally be done with an overhanging roof, suitable flashings, and the

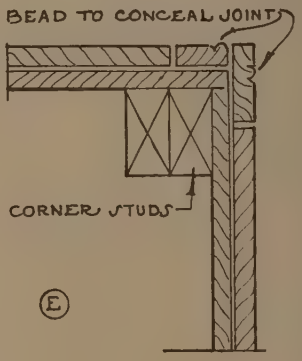


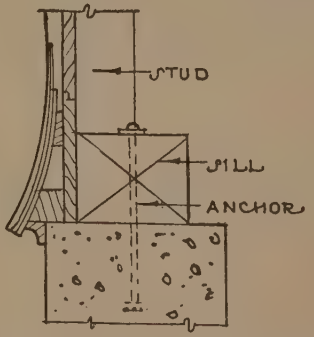
(A) WATER TABLE - SHOWING FLASHING



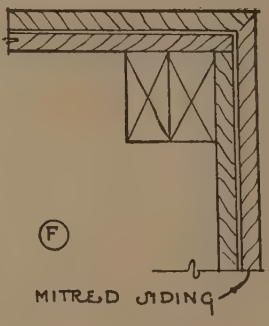


(B) WATER TABLE OF SIMPLE CONSTRUCTION





(C) WATER TABLE USED WITH SHINGLE WALL.



COVERING · FOR · OUTSIDE · WALLS

Plate 13.

use of drip grooves. It is better to confine the use of stucco to vertical surfaces. For sills, cornices, and copings, painted wood, cast cement, or tile will withstand the accumulation of water better and should be used. Whenever it is necessary to use stucco on surfaces other than vertical, the surfaces should be given the greatest possible slope, to prevent water from standing on them. Stucco is often run to the ground, and on masonry bases it may suffer no ill effect other than a bad appearance, from splash and efflorescence; but it is better to stop stucco at least 6 in. above grade, to protect it from ground moisture. This should always be done in the case of metallic lathing on frame construction. *Plate* 14 illustrates details for stucco applied to both sheathed frame construction and back-plastered frame construction.

The studs are usually 2 by 4 in. and should be run from the sills to the eaves, without intervening horizontal members, to avoid shrinkage and consequent cracking of the stucco.

Framed structures to be finished with stucco should have special bracing to prevent racking and be set on well-built foundations to avoid the possibility of settlement. Small movements due to these causes would have no effect when the structure is finished with wood siding, but when stucco is used they may cause unsightly cracking. Diagonal braces of 1 by 6-in. boards, 6 to 8 ft. long, let into the studs on their inner sides at the upper and lower corners of each wall and bridging between the studs at least once in each story height add much to the rigidity of frame walls. If sheathing is used, this bracing is not so necessary, but it is an added factor for the stability of the structure.

The framed stucco structure may be sheathed or not. The omission of sheathing is popular in California and Florida, but the tendency in other sections is to recommend horizontal rather than diagonal sheathing, as the latter sets up stresses in the stucco covering which tend to produce cracks. Good rigidity will be obtained by using the system of bracing described above, and by placing the sheathing horizontally, a considerable saving will be effected in both labor and material.

Flashing should be provided before starting the plastering at the top and on the sides of openings, wherever projecting wood trim occurs. It should also be provided across masonry walls under coping, cornices, and sills with mortar joints. The flashings should be made preferably of zinc, or galvanized special-analysis steel, or iron and should extend beyond and slightly over the face of the finished surface. Materials that will oxidize and stain the stucco should be avoided. All trim should be so placed as to show its proper projection in relation to the face of the finished stucco. Embedded trim or half timbering should be securely nailed to the sheathing or studs, and the sides of the pieces grooved so that the mortar of the scratch coat can be forced into the grooves to form water-tight joints. All roof gutters should be fixed, and down-

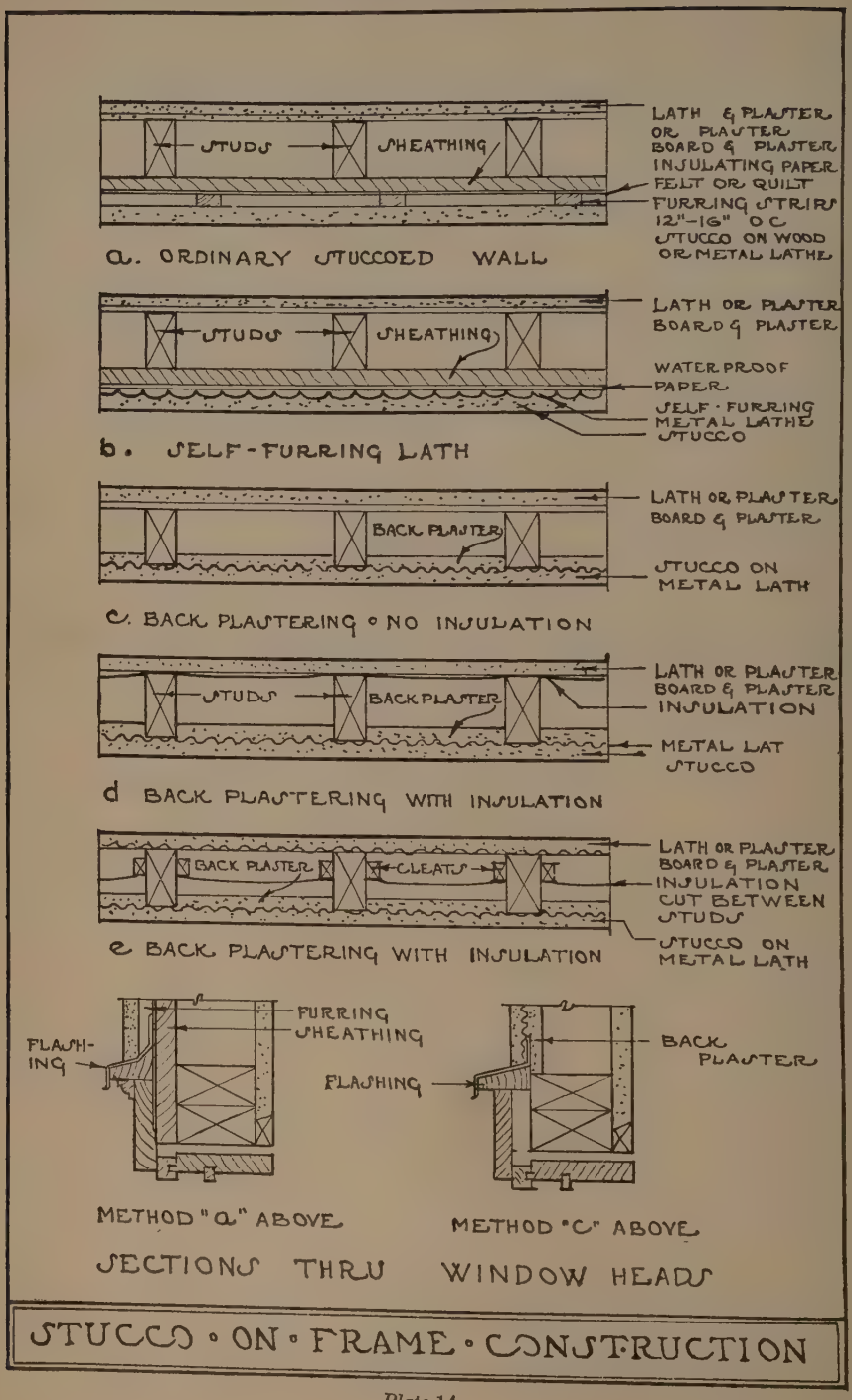

STUDS
SHEATHING
LATH & PLASTER OR PLASTER BOARD & PLASTER
INSULATING PAPER
FELT OR QUILT
FURRING STRIPS 12"-16" O C
STUCCO ON WOOD OR METAL LATHE
a. ORDINARY STUCCOED WALL
STUDS
SHEATHING
LATH OR PLASTER BOARD & PLASTER
WATER PROOF PAPER
SELF-FURRING METAL LATHE
STUCCO
b. SELF-FURRING LATH
BACK PLASTER
LATH OR PLASTER BOARD & PLASTER
STUCCO ON METAL LATH
c. BACK PLASTERING - NO INSULATION
STUDS
BACK PLASTER
LATH OR PLASTER BOARD & PLASTER
INSULATION
METAL LAT
STUCCO
d BACK PLASTERING WITH INSULATION
BACK PLASTER
CLEATS
LATH OR PLASTER BOARD & PLASTER
INSULATION CUT BETWEEN STUDS
STUCCO ON METAL LATH
e BACK PLASTERING WITH INSULATION
FLASHING
FURRING
SHEATHING
FLASHING
BACK PLASTER
METHOD "a" ABOVE
METHOD "c" ABOVE
SECTIONS THRU WINDOW HEADS
STUCCO - ON - FRAME - CONSTRUCTION

Plate 14.

spout hangers and all other fixed supports should be put in place before plastering is started, in order to avoid breaks in the stucco.

Stucco is generally placed on wood or metal lath; where wood lath is used it is possible to place any of the stucco materials, but the American Concrete Institute does not recommend wood lath for portland-cement stucco, as its brittleness requires better reinforcing. Where metal lath is used, only portland-cement or lime-mortar stuccoes should be employed. Stucco with a magnesite- cement base should never be used on anything but wood lath.

For wood-lath work, the sheathing of the walls should be covered with a heavy grade of waterproof building paper beginning at the bottom of the wall. The bottom strip should lap over the baseboard at the bottom, and each succeeding strip should lap the one below at least 2 in. It should be well fastened by large-headed roofing nails. The paper should overlap the flashings at all openings.

Wood furring strips should never be used for anything but wood lath, and in such case, they should be $\frac{7}{8}$ in. thick by $1\frac{3}{4}$ in. wide and should be nailed securely to the sheathing in a vertical position over the stud.

To the furring strips should be nailed well-seasoned, clear white pine lath; set with spacing of not more than $\frac{3}{8}$ in. and not less than $\frac{1}{4}$ in., and with vertical joints not more than seven laths high and always at bearing points.

For metal lathwork, only two types of lath are suitable. Expanded metal lath, weight not less than 3.4 lb. per square yard and heavily coated with asphaltum, is preferred for a back-plaster construction and is to be used on sheathed construction only when it can be furred out from the stucco to metallic furring strips or special fur nails to a distance of $\frac{3}{8}$ in. It should never be nailed or stapled tightly to the sheathing, only used over wood furring strips. For sheathed construction, expanded metal mesh reinforcing with openings not less than $1\frac{1}{2}$ by 4 in. of a weight not less than 1.8 lb. per square yard, separated from the sheathing by special furring nails, is preferred. Wire cloth of No. 18 gage or heavier, and with a mesh not exceeding $\frac{3}{8}$ in. square and either galvanized or asphaltum coated, is another type.

Below is given a reliable general specification for the application of stucco, but it is recommended that in both the mixing and the applying of stucco for exterior work, the instructions of the stucco material manufacturers be followed.

Where portland-cement stucco is used, it should be put on in three operations or in what is known as a *three-coat job*. White, or the natural-colored cement, may be used for the finish coat, as decided by the architect or builder. Natural-colored cement may be used for the first two coats. A finished coat of proper stucco is required where color effects are desired.

Mortar should be made of 1 part portland cement and 3 parts of clean sand, free from clay and foreign matter and of a quality equal to torpedo sand.

To each bag of cement in a batch add one-tenth of a sack of hydrated lime, thoroughly mixed. Should a coarse pebble dash or similar finish effect be desired, the aggregate for the finish coat should be of the same proportions as mentioned above, but the additional coarse ingredient needed should be incorporated in the sand, reducing the sand content by the amount of coarse aggregate thus added.

Where magnesite stuccoes are used, they should be mixed and applied in the proportions recommended by the manufacturers.

In back-plastered construction the lath is nailed or stapled directly to the studs over the furring. After two coats of plaster have been applied to the exterior face, the wall is back plastered on the inside between the studs to embed the base completely and to form a thicker wall. Often the back plastering is done after the first coat has hardened, but it appears logical that when the scratch and brown coats are applied first there is less likelihood of injury, the greater thickness caring for the necessary pressure used in applying the backing coat. The back-plastered coat usually finishes ¼ in. or more back of the outside face of the stud, and this should be chamfered on by the trowel, so that the movement of the wood frame or the expansion of the wood stud does not have any opportunity to crack the thinner section of stucco over the stud. A wall of this type loses the insulating value of the sheathing and paper, and to compensate for this, a layer of felt or other insulating material is usually applied between the studs, in such a manner that a double air space is formed between the inside plaster and the outside stucco.

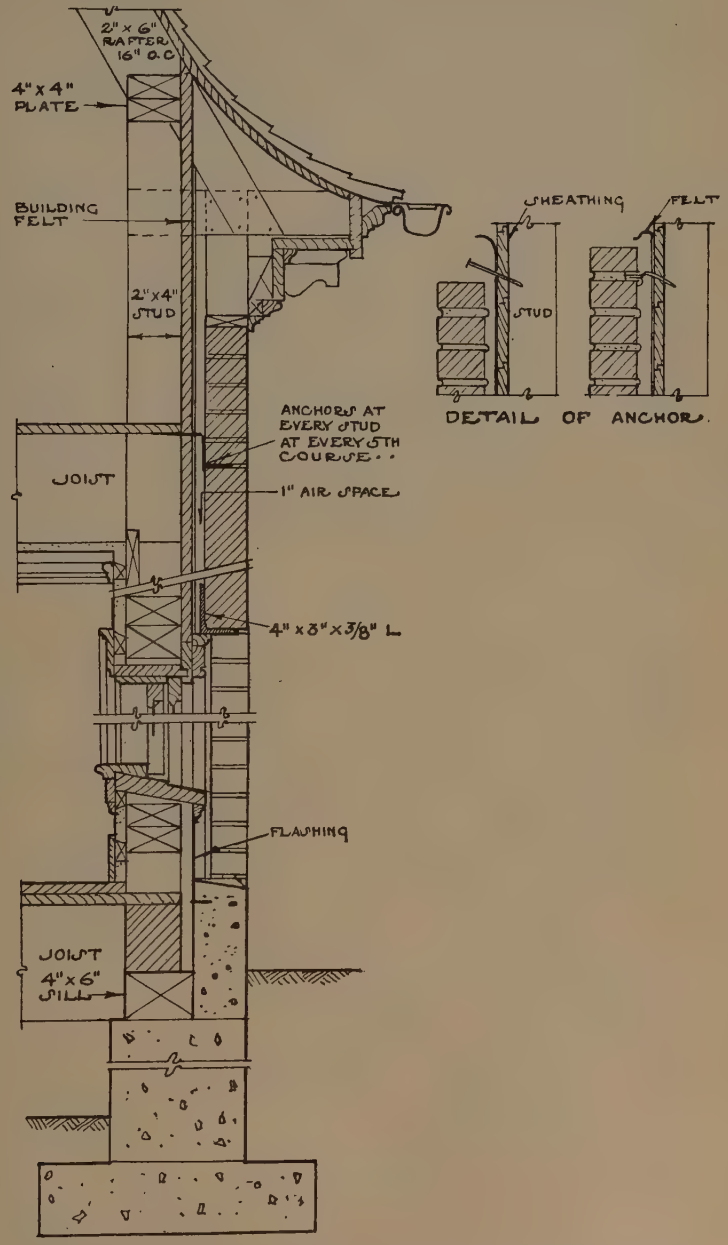
The water used for mixing stucco mortars should be suitable for drinking purposes. The usual specification requirements are that it should be clean and free from oil, acid, strong alkali, or vegetable matter.

Hair or fiber is often used in the scratch coat of stucco applied on metal lath, especially if the work is to be back plastered. It should be of first-quality long hair, free from foreign matter, or a long fiber well combed out. It should be carefully incorporated, so as to insure good distribution through the mortar with freedom from clots.

Various materials are used for coloring stucco through their incorporation into the mix. Most of them are mineral pigments. The use of oil paints for coloring is open to question, and considering the permanency of the colors it is advisable to adhere to the mineral pigments, most of which are oxides.

BRICK-VENEER CONSTRUCTION

Plate 15 shows a typical wall section of a brick-veneered house, designed for the Architects Small House Service Bureau and embodying general sound construction practices.



BRICK • VENEER • CONSTRUCTION

Plate 15.

So far as structural stability is concerned, well-built veneered dwellings may be erected under the same circumstances, and of the same height, as those with solid 8-in. brick walls. In veneer construction the foundation wall should be carried to the top of the first-floor joists.

Frame structures veneered with a single layer of brick or structural stone, attached at frequent intervals to the wooden framework or sheathing, are popular in many parts of the country.

Anchorage between brick and sheathing should be frequent, noncorrodible, and substantial; openings should be carefully flashed; and building paper should be used between the veneer and the sheathing.

As heavy rains will often drive moisture through a 4-in. brick wall, it is important to have the air space between the brickwork and the sheathing free from mortar and to have this space flashed and drained at the sill line and vented at the top into the attic. If mortar gets into the insulating air space when the brickwork is being erected, it will serve as a bridge for moisture to penetrate into the wooden framework by means of capillary attraction.

If these precautions are observed, veneered structures may be considered entirely satisfactory, and on account of the air space in the walls they will be dry and easy to heat.

CORNICES

Cornices were developed to satisfy architectural demands for a finish at the line of convergence between side walls and sloping roofs. There is no limit to the number of ways in which these converging lines may be finished. They may be finished with a simple design that barely fulfils the necessary structural requirements; or with an elaborate architectural design which will be a practical as well as an ornamental method of taking care of the rain water from the roof surface, so as to allow it to run along a gutter at the bottom of the roof; cornices nearly always include a gutter, which may be of either wood or metal. The advantage of wooden gutters, Fig. 77*a*, lies in the fact that they may be used to obtain certain architectural features as well as to serve simply the purposes of a gutter. If durable woods are used, moreover, they will probably last as long as the building itself. In cheap construction the gutter may even be omitted, the roof

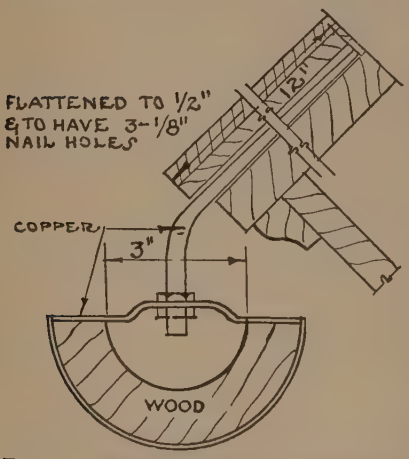


Fig. 77*a*.—Wooden gutter used extensively in New England.

rafters simply being extended far enough beyond the side walls so that water dripping from the roof will fall clear of the sides of the building. If a gutter is placed along the ends of the rafters, it should be set below the extended roof line, so that snow sliding off the roof will not strike the gutter but will readily pass over it.

Figures *a* and *b*, *Plate* 16, illustrate two methods of eave construction in which a box cornice is used. The term *box cornice* arises from the fact that the ends of the rafters are boxed in, thus shutting off from exposure to the weather the joint between the top of the side wall and the roof, and avoiding air leaks common at this point in cheap construction. It should be noted that in Figs. *a* and *b*, the side-wall sheathing is carried up to the tops of the rafters, thus securing a more nearly airtight construction. The outside of the gutter in these figures is placed below the extended roof line, for the reason above noted. In northern climates, it has been found that box cornices similar to those illustrated sometimes allow snow to settle in the gutter, and with alternate melting and freezing, the snow and ice back up under the shingles, dislodging them and causing leaks and other inconveniences to the occupants. To avoid this, a metal flashing may be turned up over the bottom course of shingles.

A simpler method, however, is to use an open cornice, as illustrated in Fig. *c*; it will be noted that here the ends of the rafters above the gutter are left open, so that the snow and ice cannot back up over the shingles but can fall through the opening between the rafters. Where this type of cornice is used, it is desirable to add a board *A* as shown in the figure, to act as a weather stop for the joint between the wall and the roof.

Figure *d* shows a wooden gutter and cornice in a very simple type of construction. The fascia board is nailed to the end of the rafters, and the wooden gutter secured to the fascia board. Note the use of angle bolts to hold the wall plate to the wall. Such bolts should always be used in good construction, particularly in sections of the country where high winds are prevalent.

Another type of cornice and gutter of simple construction is shown in Fig. *e*. In this case, the gutter is constructed of 1⅛ by 8-in. gutter board perpendicular to the roof and horizontal piece, to form the invert of the gutter, with the three-ply roofing running over and around the gutter down to the end of the roof sheathing. Note the use of fascia board at the ends of the rafter to give a more finished effect and of a finishing strip to protect the joint under the eaves.

A very satisfactory method of forming a cornice for a mansard roof over a masonry wall is shown in Fig. *g*. It should be noted that the outside of the gutter is far enough below the extended roof line to permit snow and ice to slide off without striking the gutter. In all gutters a sufficient pitch should be used to allow water to run off readily. At least 1 in. in 20 ft. should be allowed. Since the front of the gutter

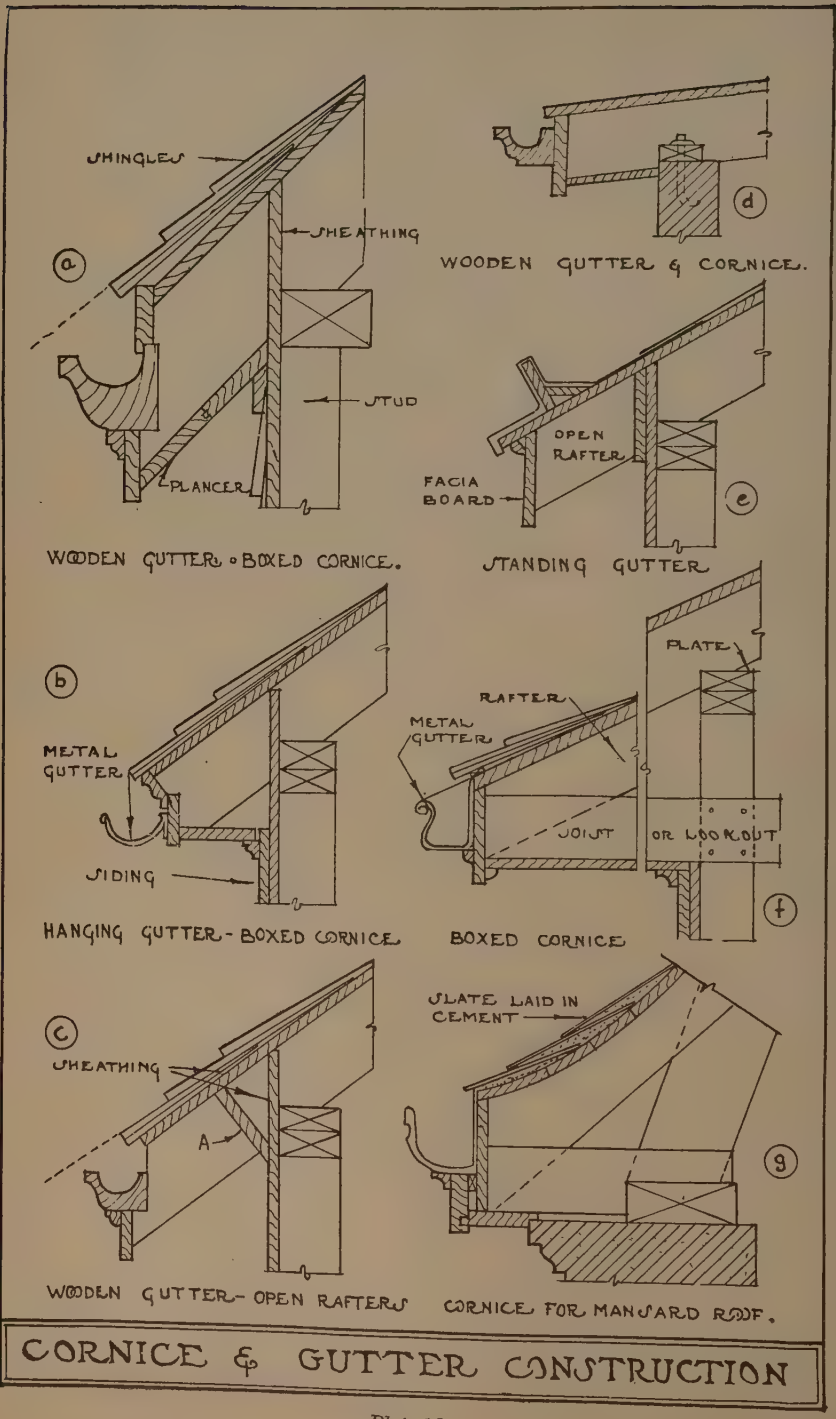

SHINGLES
SHEATHING
a
STUD
PLANCER
WOODEN GUTTER & BOXED CORNICE.
d
WOODEN GUTTER & CORNICE.
OPEN RAFTER
FACIA BOARD
e
STANDING GUTTER
b
METAL GUTTER
SIDING
HANGING GUTTER - BOXED CORNICE
PLATE
RAFTER
METAL GUTTER
JOIST
OR LOOKOUT
f
BOXED CORNICE
c
SHEATHING
A
WOODEN GUTTER - OPEN RAFTERS
SLATE LAID IN CEMENT
g
CORNICE FOR MANSARD ROOF.
CORNICE & GUTTER CONSTRUCTION

Plate 16.

should be set level for appearance's sake, it is necessary to make a false front behind which the gutter proper is given the desired pitch.

DORMERS

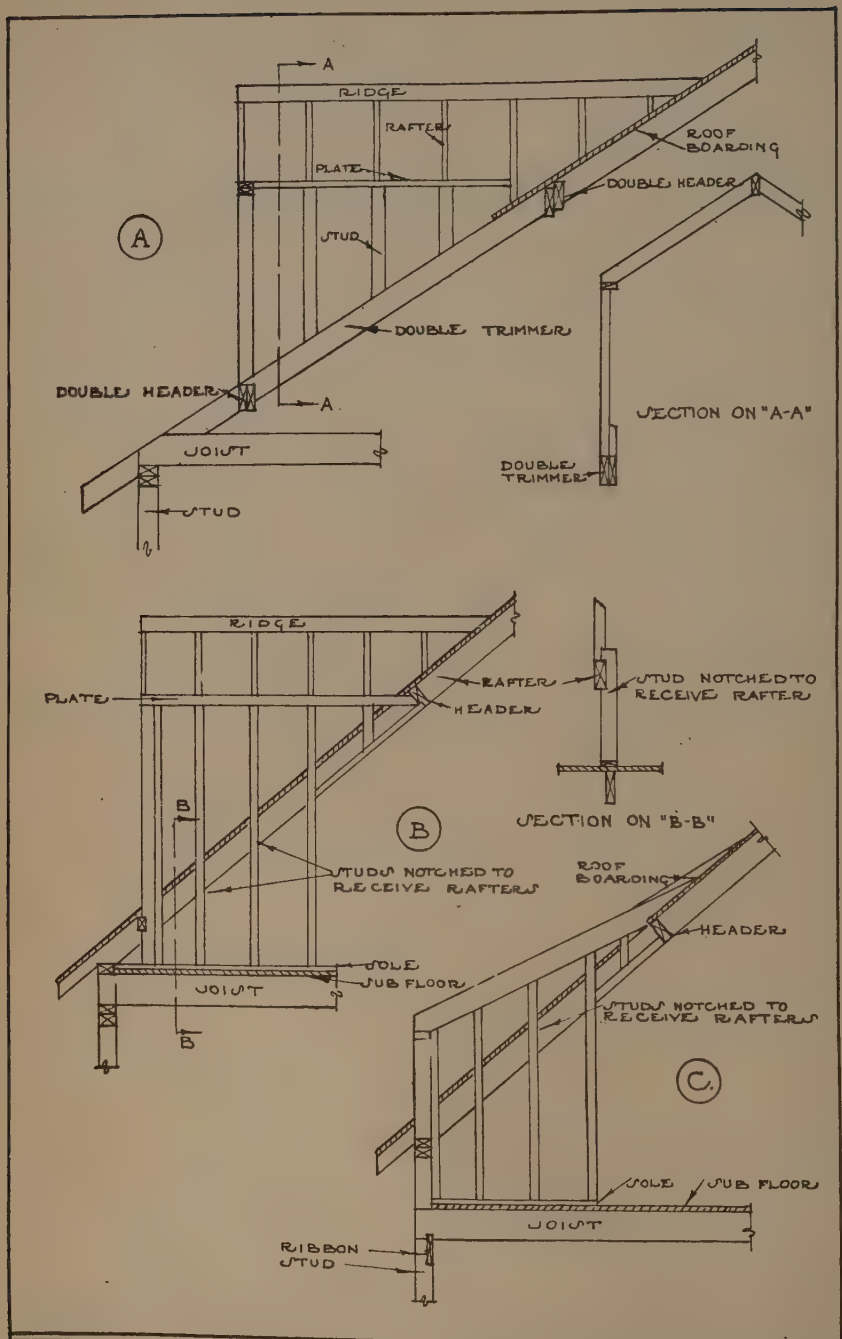
Any window of whatever type, in a roof, is called a *dormer window*. Dormers may be used to increase the light of the attic or simply as a means of obtaining a different architectural effect. There are two types of dormer construction; in one, the dormer is built on top of the roof, as shown in Fig. *a*, *Plate* 17; and in the other, the dormer is formed by continuing the side wall up the roof line, as shown in Fig. *c*.

In framing for a dormer window, an opening must be left in the roof surface; the dormer is then built up over this opening. The rafters at the sides are usually doubled, to carry the extra load. Headers, which also are usually of two pieces the same size as the rafters, are framed in at the top and bottom of the dormer opening between the two rafters at the sides of the opening. This is illustrated in Fig. *a*, which shows one of an almost endless variety of framing methods in common use. Another method is to turn the studs 90 deg. and extend them down to the attic floor level, notching them 1 in. deep around the rafter and roof boarding, in order to secure a safe construction. This method is illustrated in Figs. *b* and *c*.

In addition to openings in the roof frame for dormer windows, there must be openings for chimneys, and sometimes for skylights, or scuttles. These openings are all framed in more or less the same way as are dormer windows, although for small openings, such as a scuttle, illustrated in *Plate* 18, it is not always necessary to double the headers or rafters. Metal flashings should be used around all such openings, as indicated in the previous figure, to keep moisture from seeping into the joints between the roof coverings and the sides of the opening.

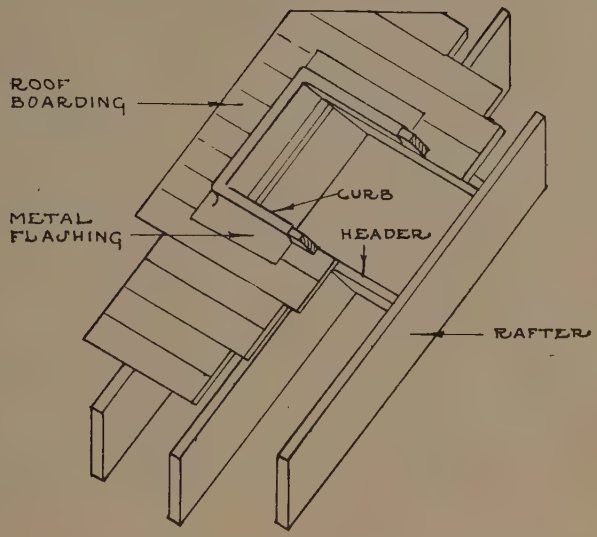
SKYLIGHTS

Skylights generally serve to admit light to a section of the attic where a dormer window would not be justified. The skylight is usually raised from 6 to 8 in. above the roof surface, to keep the glass free from snow. *Plate* 18 shows the correct method of constructing such a skylight. The most important items in connection with this type of skylight are the flashing and the provision for taking care of moisture formed by condensation on the glass. A small metal gutter at the bottom of the glass will usually be sufficient to handle this moisture, because in a small skylight it will evaporate before it overflows. For large skylights, however, a drainage pipe should be provided. A simple way of forming this gutter is to carry the flashing up around the bottom framing and bend the upper end of it into place.

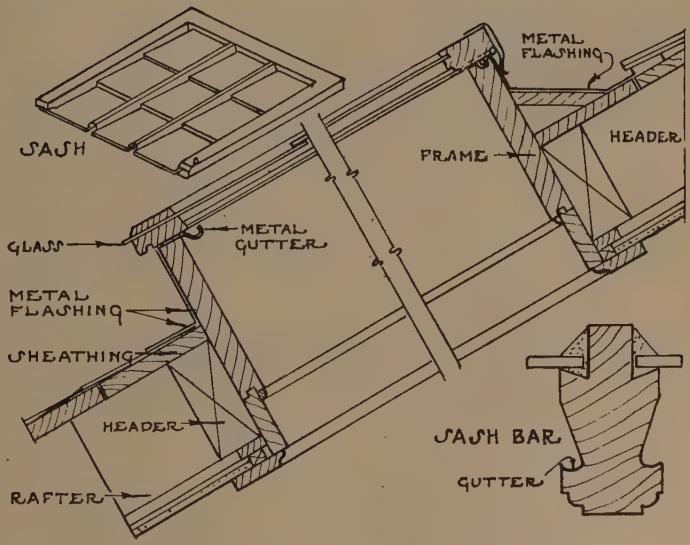


TYPICAL · DORMER · WINDOWS

Plate 17.



FRAMING AT A SCUTTLE.



FRAMING AT A SKYLIGHT.

MISCELLANEOUS · ROOF · DETAILS

Plate 18.

CHIMNEYS

In 1922, the actuarial bureau of the National Board of Fire Underwriters placed the total fire loss of 13 states in the United States at $506,541,001. This is an average of $564 per minute—$4.61 per capita, the largest annual loss ever recorded. As indicated by the following table, defective chimneys, flues, and fireplaces hold second place in the list of known causes of fire:

American Fire Losses Compared, 1921–1922

Causes	Recorded loss	
	1921	1922
Matches, smoking	$25,922,033	$25,776,961
Defective chimneys, flues, and fireplaces.	14,801,581	18,550,433
Stoves, furnaces, boilers, and pipes	13,910,531	16,676,784

Fires from defective chimneys would practically disappear if chimneys and fireplaces were properly constructed. The additional cost of following the recommendations herewith set forth will seldom exceed $15 per chimney.

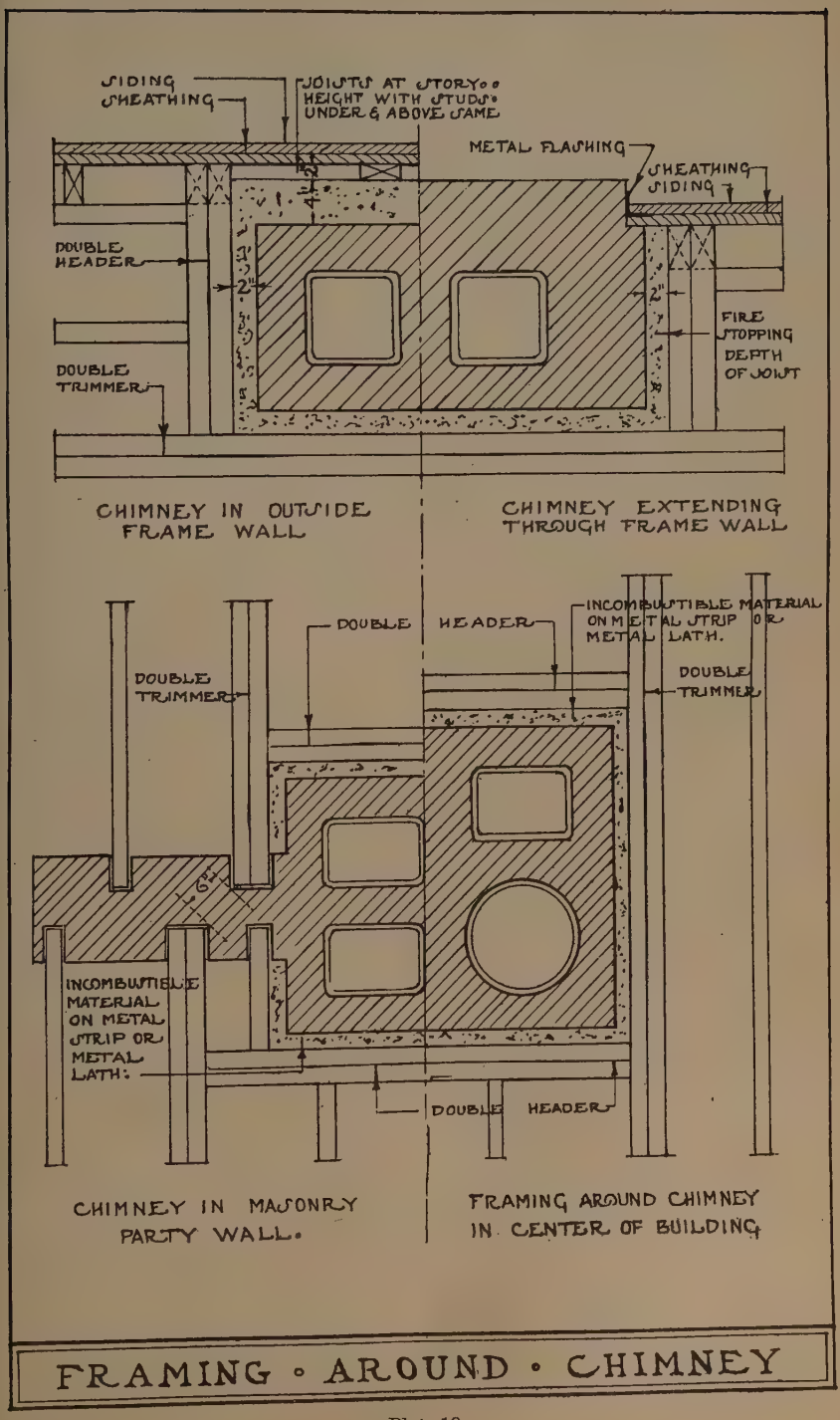
With defective chimneys and fireplaces holding first position as the worst single structural cause of fires in light building construction, it is evident that no structural feature is more important than this to the welfare of the occupants of this type of building. One requirement which all building ordinances should contain is as follows:

> No wooden beams, joists, or rafters shall be placed within 2 in. of the outside face of any chimney, whether the flues in same be for smoke, air, or for other purposes. The space between the chimney and wooden joist or beams shall be filled with loose cinders, loose mortar refuse, gypsum block, or other porous, incombustible material, to form a fire stop. Such material shall be supported by strips of sheet metal or metal lath.

The method of accomplishing this result is shown in *Plates* 19 and 20.

Build the chimney from the ground up. Let the foundation carry all the weight, be carefully designed for local soil conditions, and be placed well below the frost line.

Concrete or other masonry foundations, of strength sufficient to carry the weight imposed without danger of settlement or cracking, are required. In the masonry of chimneys, all joints should be carefully filled and pointed, and the space between flue linings and the inside of the masonry slushed full. The National Board of Fire Underwriters recommends that chimneys be laid up in a 1:3 portland-cement mortar. All joints between flue-lining sections should be carefully pointed on the inside. Flue sections should always be set, before the enclosing masonry is built up.



FRAMING • AROUND • CHIMNEY

Plate 19.

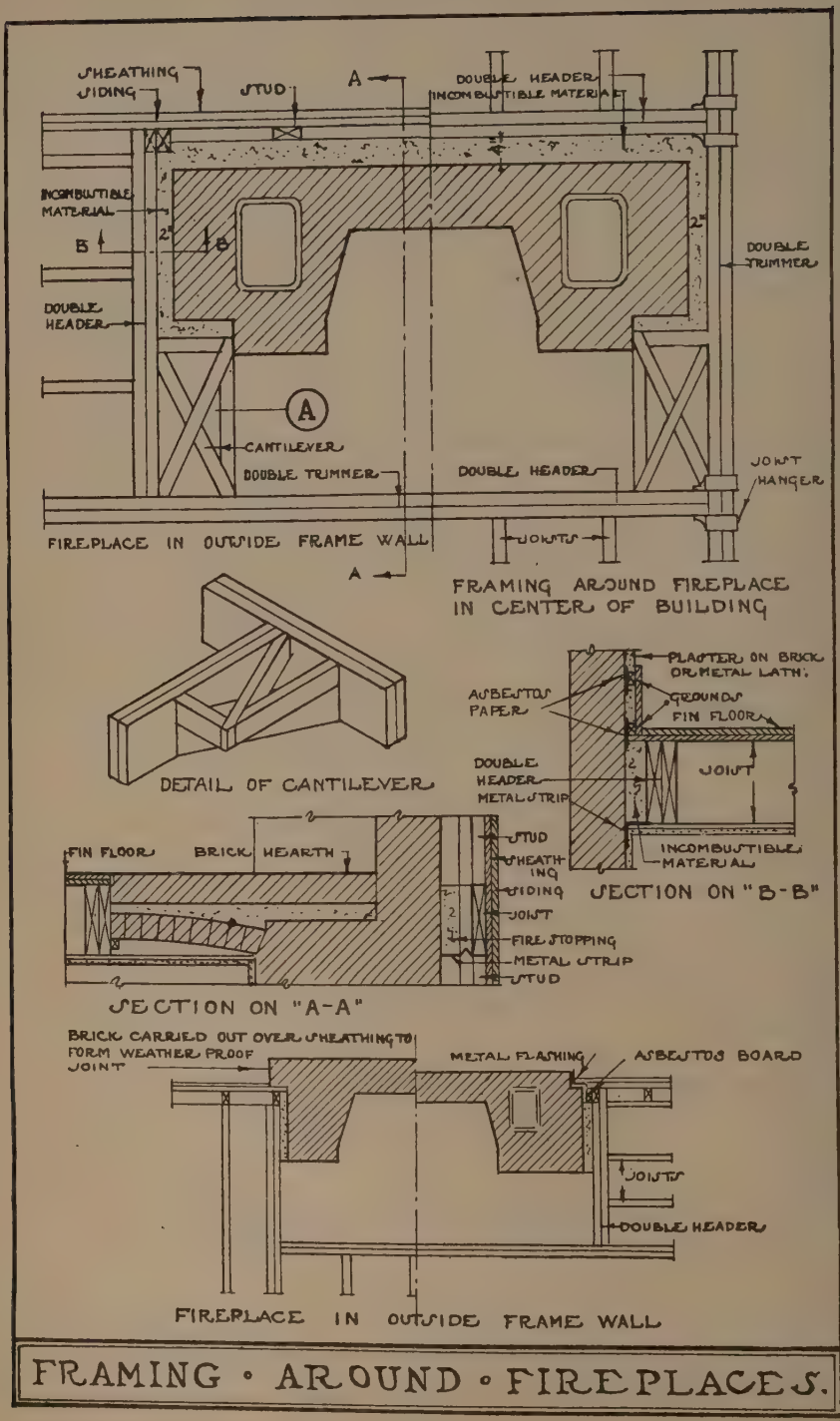

SHEATHING
SIDING
STUD
A
DOUBLE HEADER
INCOMBUSTIBLE MATERIAL
INCOMBUSTIBLE MATERIAL
B
2"
8"
2"
DOUBLE TRIMMER
DOUBLE HEADER
A
CANTILEVER
DOUBLE TRIMMER
DOUBLE HEADER
JOIST HANGER
FIREPLACE IN OUTSIDE FRAME WALL
JOISTS
A
FRAMING AROUND FIREPLACE IN CENTER OF BUILDING
DETAIL OF CANTILEVER
PLASTER ON BRICK OR METAL LATH.
ASBESTOS PAPER
GROUNDS
FIN FLOOR
DOUBLE HEADER
METAL STRIP
JOIST
2
5
INCOMBUSTIBLE MATERIAL
SECTION ON "B-B"
FIN FLOOR
BRICK HEARTH
STUD
SHEATHING
SIDING
JOIST
FIRE STOPPING
METAL STRIP
STUD
2
5
SECTION ON "A-A"
BRICK CARRIED OUT OVER SHEATHING TO FORM WEATHER PROOF JOINT
METAL FLASHING
ASBESTOS BOARD
JOISTS
DOUBLE HEADER
FIREPLACE IN OUTSIDE FRAME WALL
FRAMING • AROUND • FIREPLACES.

Plate 20.

Tops of chimneys should extend at least 3 ft. above flat roofs, and 2 ft. above the ridges of peak roofs, and should be properly capped. The flue lining should project at least 4 in. above the chimney top, to allow for a 2-in. wash and a 2-in. projection. This prevents disintegration of the chimney by freezing and thawing, as there is no chance for water to collect and remain around the top of the flue and in the crevices between the mortar and masonry. The wash should be formed of a cement mortar or cut in the stone.

A good weatherproof connection between the exterior stud wall and the chimney should be secured; the chimney wall, in such cases, should be not less than 8 in. thick. A slight offset should be provided, in order that the sheathing may lap over and produce a right-angled joint, to prevent the passage of the elements. It is of the utmost importance that wood members be properly separated from chimney construction and not come into contact with any part of it. The lumber should be protected from the chimney by the insertion of asbestos board, or its equivalent. Ample space should be provided for the insertion of fire-stopping materials to prevent radiated heat from affecting woodwork and also to provide for settlement in the masonry after construction is completed. This is illustrated in *Plate* 20. Chimneys must not rest upon or be carried by lumber-built floors, or brackets, or be hung from any lumber-built construction whatever. Neither should they be supported on iron brackets or stirrups attached to lumber-built construction, no matter how carefully devised.

In ordinary masonry wall construction, it is quite usual to embed nailing strips, such as lath, in the joints between courses of brickwork, to which furring strips or trim are nailed. This practice should never be followed in chimney construction. No combustible material of any kind should be placed in joints of units making up a chimney. Plastering should be directly on the masonry, or on incombustible lathing and furring material. Furring strips, when used to support base or other trim around chimneys, should be insulated from the masonry by asbestos paper, or equivalent material, at least $\frac{1}{8}$ in. thick.

Special caution should be used in keeping smoke-pipe intakes at least 18 in. below wood, lath, and plaster, combustible ceilings, or open joists, unless all woodwork directly over the pipe is protected by asbestos or similar material. The intakes to the flues should always enter the chimney through the side and should be of fire clay, or metal thimbles, set securely in the chimney wall with mortar. No woodwork should be placed within 6 in. of such a thimble.

It is often necessary to erect a chimney with a stud wall on one or two sides, making it impossible to place plaster directly upon chimney construction. When this is the case, the lumber studding and the joists should be insulated and separated from the chimney, as shown by *Plate*

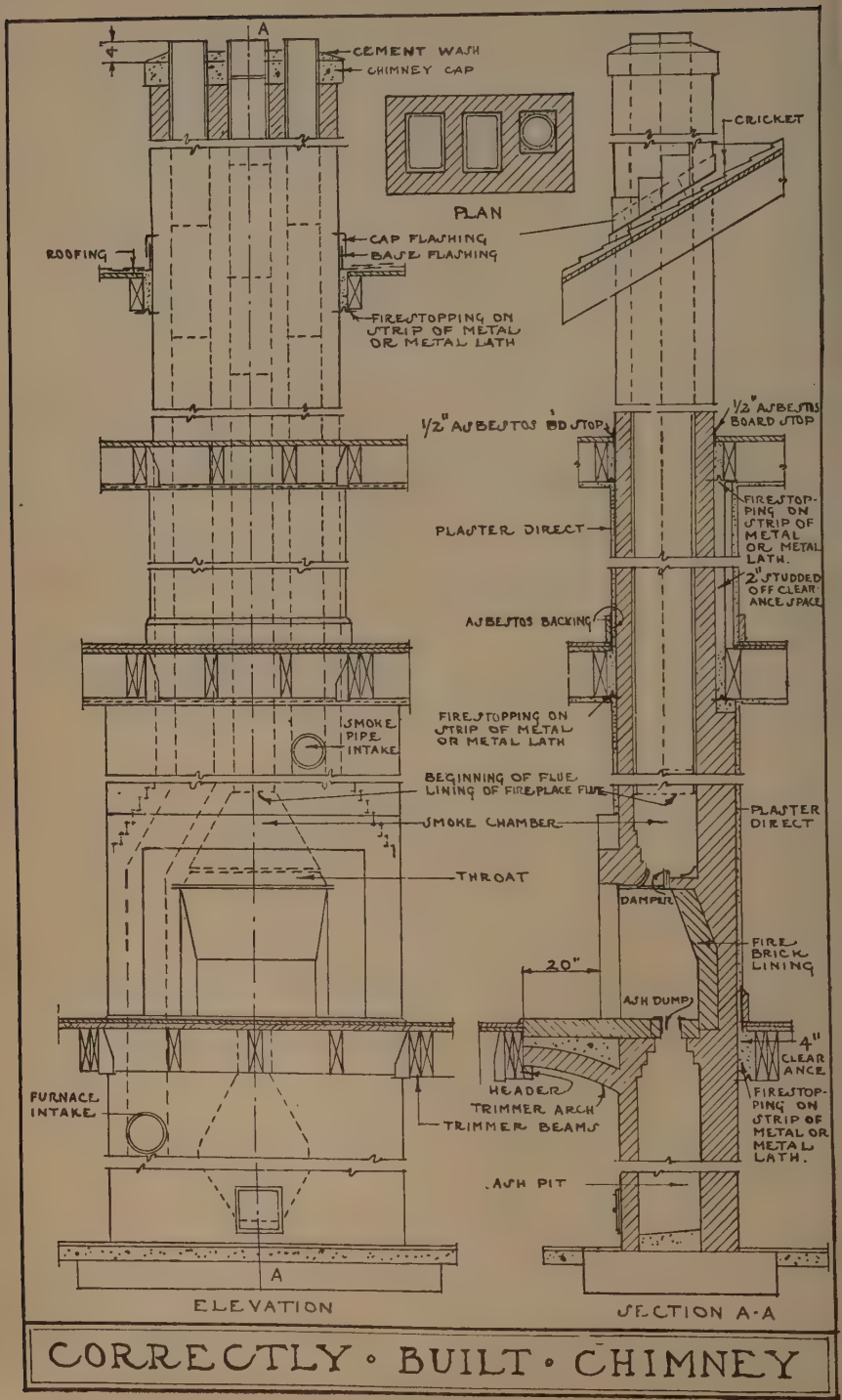

CEMENT WASH
CHIMNEY CAP
PLAN
CRICKET
ROOFING
CAP FLASHING
BASE FLASHING
FIRESTOPPING ON STRIP OF METAL OR METAL LATH
½" ASBESTOS BD STOP
½" ASBESTOS BOARD STOP
PLASTER DIRECT
FIRESTOPPING ON STRIP OF METAL OR METAL LATH.
2" STUDDED OFF CLEARANCE SPACE
ASBESTOS BACKING
SMOKE PIPE INTAKE
FIRESTOPPING ON STRIP OF METAL OR METAL LATH
BEGINNING OF FLUE LINING OF FIREPLACE FLUE
SMOKE CHAMBER
PLASTER DIRECT
THROAT
DAMPER
FIRE BRICK LINING
20"
ASH DUMP
4" CLEARANCE
FURNACE INTAKE
HEADER
TRIMMER ARCH
TRIMMER BEAMS
FIRESTOPPING ON STRIP OF METAL OR METAL LATH.
ASH PIT
A
A
ELEVATION
SECTION A-A
CORRECTLY • BUILT • CHIMNEY

Plate 21.

20. An independent chimney may be erected in the center of a building. The careless builder sometimes uses it to support the floor joists, perhaps adding a few inches of brick to the thickness of the chimney walls to support the additional load. Such construction will develop a very serious hazard. The shrinkage of the lumber members will not be the same as the settling of the masonry chimney. Thus, in addition to plaster cracks, it is almost certain that the chimney joints will open up and furnish a passage for flame and sparks into the concealed hollow spaces between the joists. Lumber should not rest directly upon any chimney construction. The joists around it should be supported by headers and trimmers, as shown.

In many sections, masonry party walls between buildings are usual. Where flues or chimneys are a portion of such party walls, the flues should not extend beyond the center of the walls. An example of this and of the minimum separation for the ends of lumber joists entering party walls is shown in *Plate* 19. Where there is no right-angled joint, as shown in the detail, the separation between the ends of joists should not be less than 8 in.

In order to ascertain the proper flue sizes and requirements for any particular installation, reference should be made to the handbooks of reputable furnace and boiler manufacturers.

Plate 21 shows sections through a chimney constructed according to approved standards.

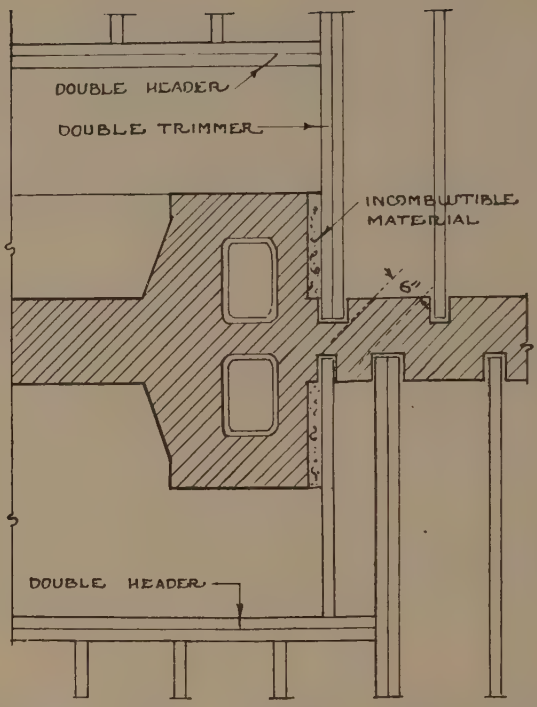
FIREPLACES

An open fireplace has no equal as a ventilator and purifier and may well be used in the cool days of spring and fall in place of the furnace, for heat, ventilation, and the creating of a home atmosphere. A properly constructed fireplace will carry all the smoke up the chimney, serve as a general ventilating medium, and radiate the maximum amount of heat into the room. Woodwork for mantels, shelves, or lumber framing should be so placed as to avoid fire hazards. Several details which will obviate danger may be included in the design for any house without much additional expense and they are here presented.

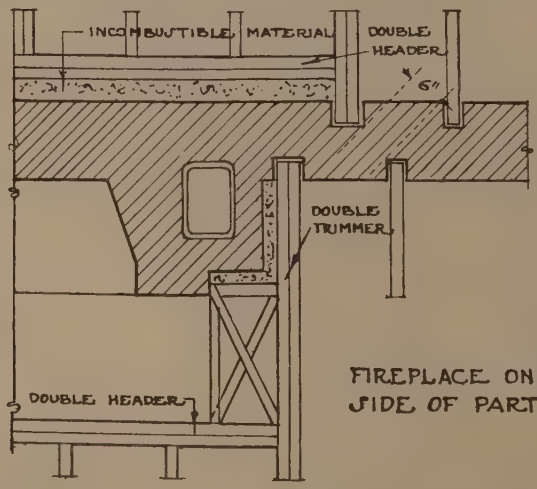
Plate 21 also illustrates a properly built fireplace and chimney. The chimney has two flues, one for the fireplace and one for the furnace. Note that the chimney is practically independent of the framing around it.

To insure satisfactory results from an open fireplace, it is essential that

1. The flue have the proper area.
2. The throat be correctly proportioned and located.
3. A properly constructed smoke shelf and chamber be provided.
4. The chimney be carried high enough to avoid interference, and



FIREPLACES BACK TO BACK IN PARTY WALLS



FIREPLACE ON ONE SIDE OF PARTY WALL.

FIREPLACES IN PARTY WALLS.

Plate 22.

5. The shape of the fireplace be such as to direct a maximum amount of radiated heat into the room.

The header beam which supports the trimmer arch of the fireplace should be at least 20 in. from the chimney breast. The hearth itself should be of incombustible material at least 4 in. thick, and any lumber centering used temporarily to support the hearth should be removed; this should be particularly specified, as the carpenter is very apt to leave the centering in place. The length of the hearth and the trimmer arches should be at least 24 in. longer than the fireplace opening. Many architects and builders prefer to use a reinforced-concrete slab instead of a trimmer arch, to support the hearth. Many times, the hearth is of less width than the fireplace breast. If an ornamental mantelpiece is used around the fireplace opening, it is desirable to plaster up to that point. The detail at *A*, *Plate* 20, shows the method of carrying the floor by a cantilever support, to permit such plastering.

No wooden mantel or other woodwork should be placed within 8 in. of the jamb, or within 12 in. of the soffit, of any open fireplace. A combustible summer piece, or fire board, should not be made to close the fireplace when not in use. At times, it is desired to set the fireplace in the outside wall of a building; *Plate* 20 shows the proper method for such construction, with the necessary separation of the headers from the chimney. The space between the headers and the chimney for the fireplace should be at least 2 in. and should be filled in with incombustible material supported by a metal strip or metal lath, as shown in the figure. Where the fireplace extends through the frame wall, there should be at least 8 in. of brickwork between the lumber and the flue lining. An offset should be provided in the masonry, so that the sheathing may lap over and make a right-angled weatherproof joint, which is filled in with asbestos board to make it fire safe and to prevent the entrance of weather into the building.

Plate 22 shows details of fireplaces in party walls.

FIRE STOPPING

In the properly constructed building, fire stopping is provided at certain vital points to check, for an appreciable time, the passage of flames from one floor or section to another.

It is necessary to close effectively any concealed open spaces in the walls or floors, so that air cannot pass the barrier. Any material, or any combination of materials, what will accomplish this purpose, may be considered suitable fire-stopping material. Lumber fire stops, consisting usually of solid blocking, are economical, inexpensive, and easy to install. Incombustible materials, such as mineral wool, crushed mortar, plaster, concrete, hollow tile, or gypsum block, may be used effectively as dry fill, on top of, or in behind, the fire stops.

Fire stops, in addition to serving the main purpose of retarding the progress of fire, also appreciably decrease heat losses by breaking the open wall spaces at each story. There is, therefore, a direct saving in fuel. By acting as a barrier to the travel of rats, mice, and other rodents through the house, they more than justify the slight additional expense which they entail. No fire stopping should be concealed until the architect has had an opportunity to inspect it. The three most vulnerable points in a building as regards the spread of fire are (1) between the lower floor joists, at the sills and at partitions; (2) between the second floor joists at the wall supports; and (3) between the roof rafters at the eaves. Stops at these points will check a fire, for an appreciable time, from spreading through the fluelike passages between the wall studs and frequently allow it to be extinguished with little damage.

Fig. *a*, *Plate* 23 illustrates the use of fire stops at the sills; by filling with an incombustible material, the effectiveness of the stop would be considerably increased.

Special care should be taken to shut off the cellar or basement from the first floor. Many residence fires start where the heating equipment is located and are readily communicated if adequate fire stopping has not been employed. Some builders even advocate the added precaution of using a metal lath for the basement ceiling, at least over the boiler room.

Fig. *b* shows the method of fire stopping at the second floor of a balloon-framed building. Two fire stops are required, one between the studs to prevent vertical drafts and the other between the joists to prevent horizontal drafts from passing up through ducts formed by the studding and the surfacings on each side.

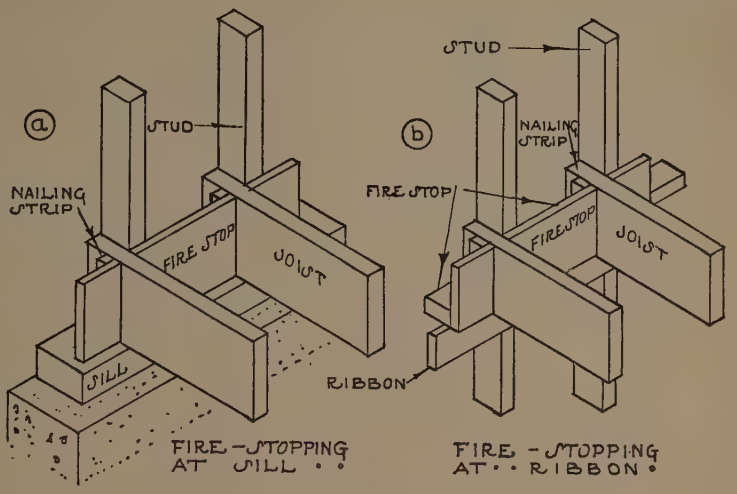
The method of framing the western and braced-framed building automatically provides a fire stop (the plate) against vertical drafts, and the nailing strip between the joists and against the foot of the studs acts as a stop to prevent fire spreading from the walls, under the flooring.

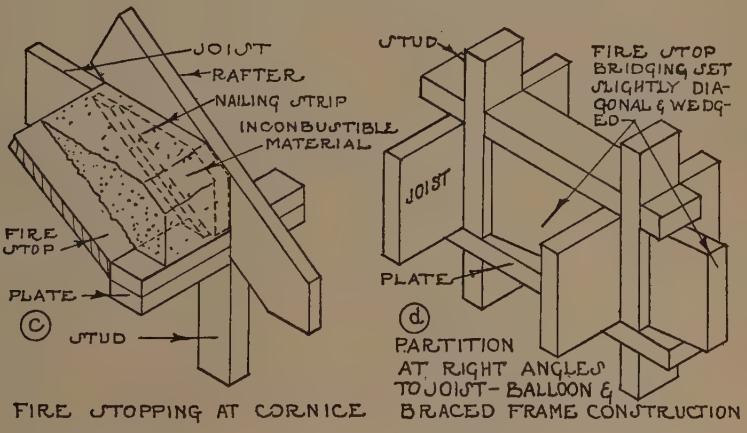
The spaces above the plates and between the rafters should be tightly stopped. Attics are sometimes difficult of access and are often used as storehouses for highly combustible materials. Besides the protection from a fire within, a roof constructed with fire stops offers protection from fire in an adjoining building.

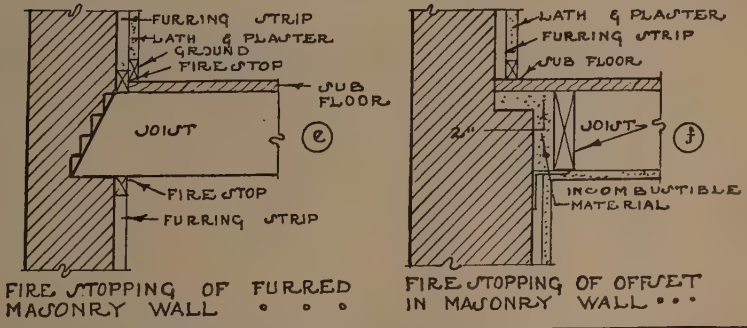
Cornices are always troublesome in case of fire. They are usually dry and burn freely. It is wise, therefore, to provide a fire stop at the intersection of the attic joists and stud wall, as shown in Fig. *c*.

Figure *d* illustrates fire stopping at a partition. At a sliding door where a fire is particularly difficult to extinguish, the pocket in which the door slides should be lined with asbestos.

More complete fire stopping involves the blocking off of all concealed air passages, not only in the walls, as already described, but also







FIRE-STOPPING · TYPICAL · DETAILS

Plate 23.

in the floors, at all intersections of walls and floors, to check a fire from spreading horizontally, and in clothes chutes and other shafts.

Such additional fire stopping, although considered by some as being in the nature of a refinement, can by no means be considered as superfluous, and if not justified in the speculative house built with the utmost economy, it will be found that in the better-class structure such complete fire stopping will often pay for itself many times over.

The general principles of fire stopping also apply to masonry-veneered and masonry-walled houses, with the exception that slight differences are necessitated by the open space between veneering and sheathing on the one hand and by the furring on exterior and interior masonry walls on the other.

In the case of houses veneered with masonry, a space is generally left between the veneering and the sheathing of the frame wall. A fire within this space is an exceptionally difficult one to locate exactly. For this reason, the space between the veneering and the outside surface of the frame wall should be fire-stopped with horizontal strips at the floor lines. These horizontal lumber strips will accumulate sufficient mortar droppings to act as an effective seal and perform fire-stopping functions satisfactorily.

Where masonry walls are furred, the masonry between the ends of the lumber joists should project to the thickness of the furring beyond the inner face of the wall, either the full depth of the joists or a double course above and below. The method which continues the inner face of the wall flush and places horizontal furring strips above and below the joists, illustrated in Fig. *e*, *Plate* 23, is equally effective.

Where walls are studded off, as they sometimes are in a stairway in order to maintain a plane surface, the space between the inside face of the wall and the joists at the floor level should be fire-stopped with brickwork or other incombustible material.

FLASHING

The term *flashing* is applied to any strip of material (usually metal) which is placed over a joint to make it watertight. Flashings are necessary in many places, such as around windows and doors and hips, valleys, and ridges of roofs, chimneys, dormers, etc.

The more commonly used flashings are of copper, tin, lead, zinc, and galvanized iron. Of these, copper is generally considered the best. It is permanent, easily worked and shaped, requires no painting or other treatment, and costs but little more than other sheet metals. The minimum weight that should be used for any flashing is 16-oz. copper, and for the highest class of work, 18 or 20-oz. metal is recommended. On account of galvanic action leading to disintegration, copper should be

insulated from all iron, steel, and zinc, either by asbestos, sheet lead, or by tinning the iron, if the area is small.

If tin or galvanized iron is used, it should be well painted on the underside before being placed; and on the top after being placed. At least IX tin, approximately 28 U. S. gage should be used, and at least a 24-gage galvanized iron; but this latter material is seldom satisfactory as flashing.

Sheet lead when used should weigh at least 3 lb. per square foot for the ordinary roof flashing. It should be installed to permit expansion and contraction, and in no case should it be secured by nailing directly through the sheet. Instead, sheet lead should be held with cleats of copper or lead, which, in turn, should be fastened to the wood by means of copper-wire nails.

Lead is often desirable as a flashing material on account of its great pliability and durability under ordinary atmospheric conditions.

Zinc flashings should be at least 11 zinc gage (0.024 in. thick) and should be fastened in place by zinc cleats and not nailed. Zinc, as well as copper and lead, is an extremely lasting material for flashing purposes.

The following figures illustrate various applications of flashing in the ordinary building. The use of resin-sized or asbestos-felt building paper under all flashings is recommended. Flashings should be arranged to overlap generously and so allow for any movement that may occur in the chimney or roof.

Figure *a*, *Plate* 24, shows flashing around a chimney with the use of a "cricket" or "saddle" to throw the water away from the back of the chimney.

In flashing an "open" valley on a roof as in Fig. *b*, the distance from the bottom of valley to the edge of shingles should be at least 2 in. at the narrow or upper part and increase ½ in. every 8 ft. toward the gutter. The flashing should extend far enough under the shingles to be covered by at least two thicknesses. Flashings should be secured by cleats nailed to the wood sheathing, with the ends of the cleats turned back over the nail heads, as indicated in Fig. *b*. In Fig. *c* is shown another variation of the open valley.

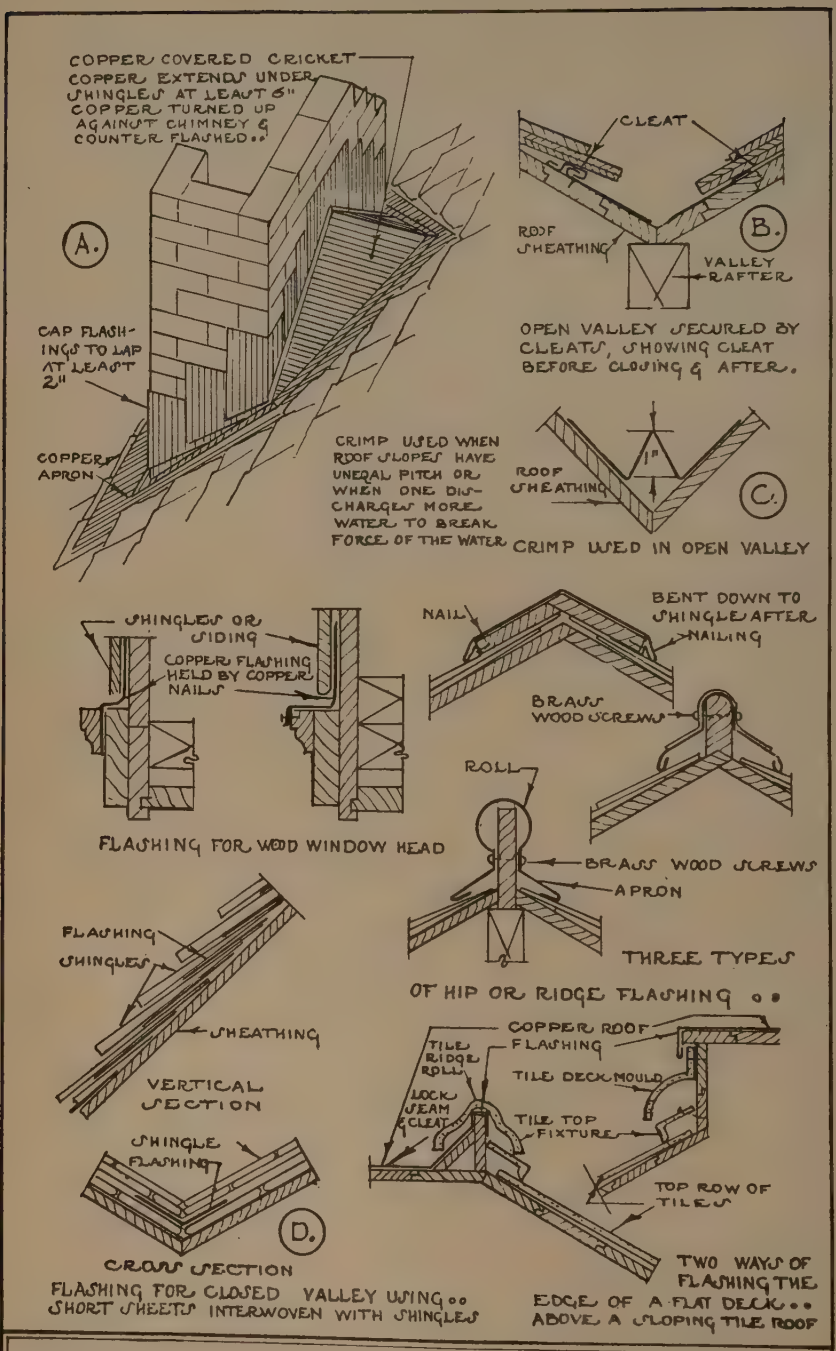
Figure *d* shows a common method of flashing a closed-valley roof. Each piece of copper or other metal should lap the one below at least 3 in.

Another method is to lay the flashing directly on the sheathing, in long sheets lapped 4 in. or else soldered together.

The other figures on *Plate* 24 show miscellaneous details of approved flashing methods.

PREPARATION FOR TILE AND CEMENT FLOORS

In tile installations such as that used for a bathroom in the modern house, certain precautions should be taken as to the framing and car-


COPPER COVERED CRICKET
COPPER EXTENDS UNDER SHINGLES AT LEAST 6"
COPPER TURNED UP AGAINST CHIMNEY & COUNTER FLASHED
A.
CAP FLASHINGS TO LAP AT LEAST 2"
COPPER APRON
CRIMP USED WHEN ROOF SLOPES HAVE UNEQUAL PITCH OR WHEN ONE DISCHARGES MORE WATER TO BREAK FORCE OF THE WATER
CLEAT
ROOF SHEATHING
VALLEY RAFTER
B.
OPEN VALLEY SECURED BY CLEATS, SHOWING CLEAT BEFORE CLOSING & AFTER.
1"
ROOF SHEATHING
C.
CRIMP USED IN OPEN VALLEY
SHINGLES OR SIDING
COPPER FLASHING HELD BY COPPER NAILS
FLASHING FOR WOOD WINDOW HEAD
NAIL
BENT DOWN TO SHINGLE AFTER NAILING
BRASS WOOD SCREWS
ROLL
BRASS WOOD SCREWS
APRON
THREE TYPES OF HIP OR RIDGE FLASHING
FLASHING
SHINGLES
SHEATHING
VERTICAL SECTION
SHINGLE FLASHING
D.
CROSS SECTION
FLASHING FOR CLOSED VALLEY USING SHORT SHEETS INTERWOVEN WITH SHINGLES
COPPER ROOF FLASHING
TILE RIDGE ROLL
TILE DECK MOULD
LOCK SEAM & CLEAT
TILE TOP FIXTURE
TOP ROW OF TILES
TWO WAYS OF FLASHING THE EDGE OF A FLAT DECK ABOVE A SLOPING TILE ROOF

MISCELLANEOUS · FLASHING · DETAILS.

Plate 24.

pentry work. The following suggestions are considered good practice.

1. All joists under floors to be tiled should frame with trimmers and headers in such manner that it will not be necessary to do any cutting of joists in order to accomodate soil pipes, and so that a minimum amount of cutting will be necessary for any other pipes.

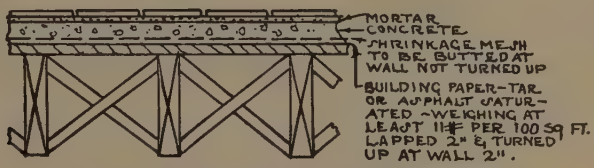

MORTAR
CONCRETE
SHRINKAGE MESH TO BE BUTTED AT WALL NOT TURNED UP
BUILDING PAPER-TAR OR ASPHALT SATURATED -WEIGHING AT LEAST 11# PER 100 SQ FT. LAPPED 2" & TURNED UP AT WALL 2".

FIG. 78.—Tile floor on new wood construction.

2. Joists under tiled floors shall be bridged at least once in their span, not over 5 ft. apart, and with not less than 1 by 2-in. cross-bridging, accurately fitted and nailed at each end with two nails (8 d.).

3. Wherever so shown, or practicable, the floor joists should be lowered to the depth required for the construction of the tile floors. On top of such joists a floor may be laid of not less than 1-in.-thick by

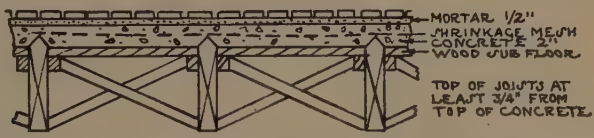


FIG. 79.—Method of placing tile floors on new or old wood construction.

not over 6-in.-wide boards, placed about $\frac{1}{4}$ in. apart and securely nailed to each joist.

4. Where floor joists are not lowered, their tops should be beveled off to a sharp edge. To the sides of the joists, at the distance below the finished floor required for the construction of the tiled floors, securely nail not less than 1 by $2\frac{1}{2}$-in. cleats, and between the joists cut and set 1-in.

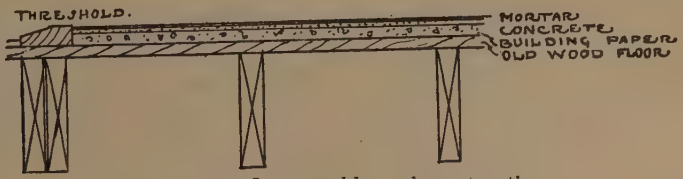


FIG. 80.—Tile floor on old wood construction.

by not over 6-in.-wide boards laid about $\frac{1}{4}$ in. apart and securely nailed to the cleats (see Figs. 78, 79, and 80, which show sections through typical tile installations).

Where side walls are to be tiled, 12-in. stud spacing is preferred to the more usual 16-in. Provided a heavier metal lath is used, however, 16-in. spacing is satisfactory. Building paper is used in either case.

Waterproof building paper weighing at least 11 lb. to 100 sq. ft. should be placed between wood floors and concrete setting beds. The paper should be lapped at least 2 in. and turned up at walls at least 2 in., to prevent the wood from absorbing moisture from the concrete.

FARM AND OTHER SPECIAL-PURPOSE BUILDINGS

Plans and details of buildings under this classification are shown in the following pages. In general, the same principles of good construction should prevail in such buildings, as should prevail in all other light building construction. Certain modifications in detail, however, can be made in buildings in these important fields, depending upon the particular use to which the building is to be put. A section tool house on a railroad, for

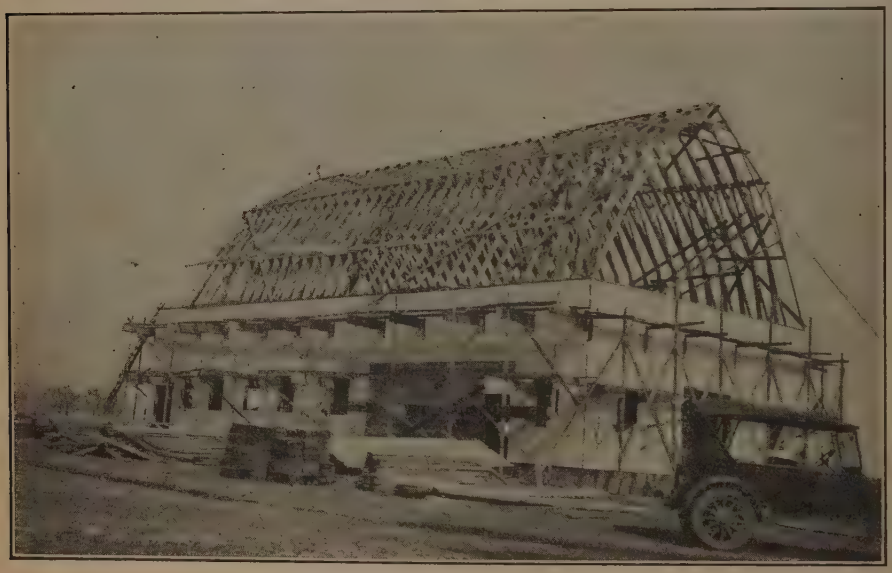
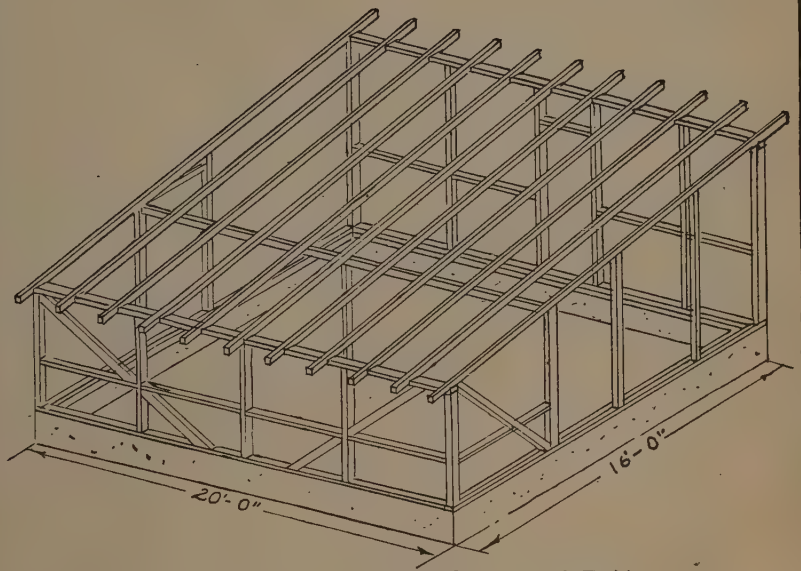
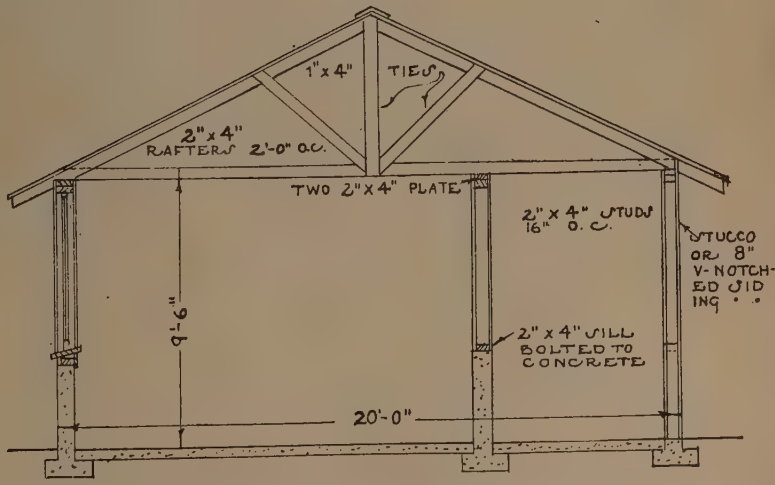


FIG. 81.—Gambrel roof farm barn.

example, should be rainproof; but there is no need of incurring the expense of extra sheathing or building paper to keep out wind. Small buildings, on the farm and on the railroads, which are not finished inside, and often are not even heated, require a less expensive type of construction. In barns and poultry houses and other structures housing stock, taking the same precautions against slight settlement due to shrinkage, or deflection, that would be taken in designing or building a residence is not justified. In structures of the former class, plaster cracks do not have to be considered, fire stops are unnecessary, and such precautions as laying sheathing diagonally instead of horizontally are unwarranted. Temperature control, however, should be considered in erecting such buildings, as it is now recognized as being even more vital than ventilation in obtaining the best results from live stock.



POULTRY HOUSE BARN



SECTION THRU MILK HOUSE.

TYPICAL · FARM · BUILDINGS.

Plate 25.

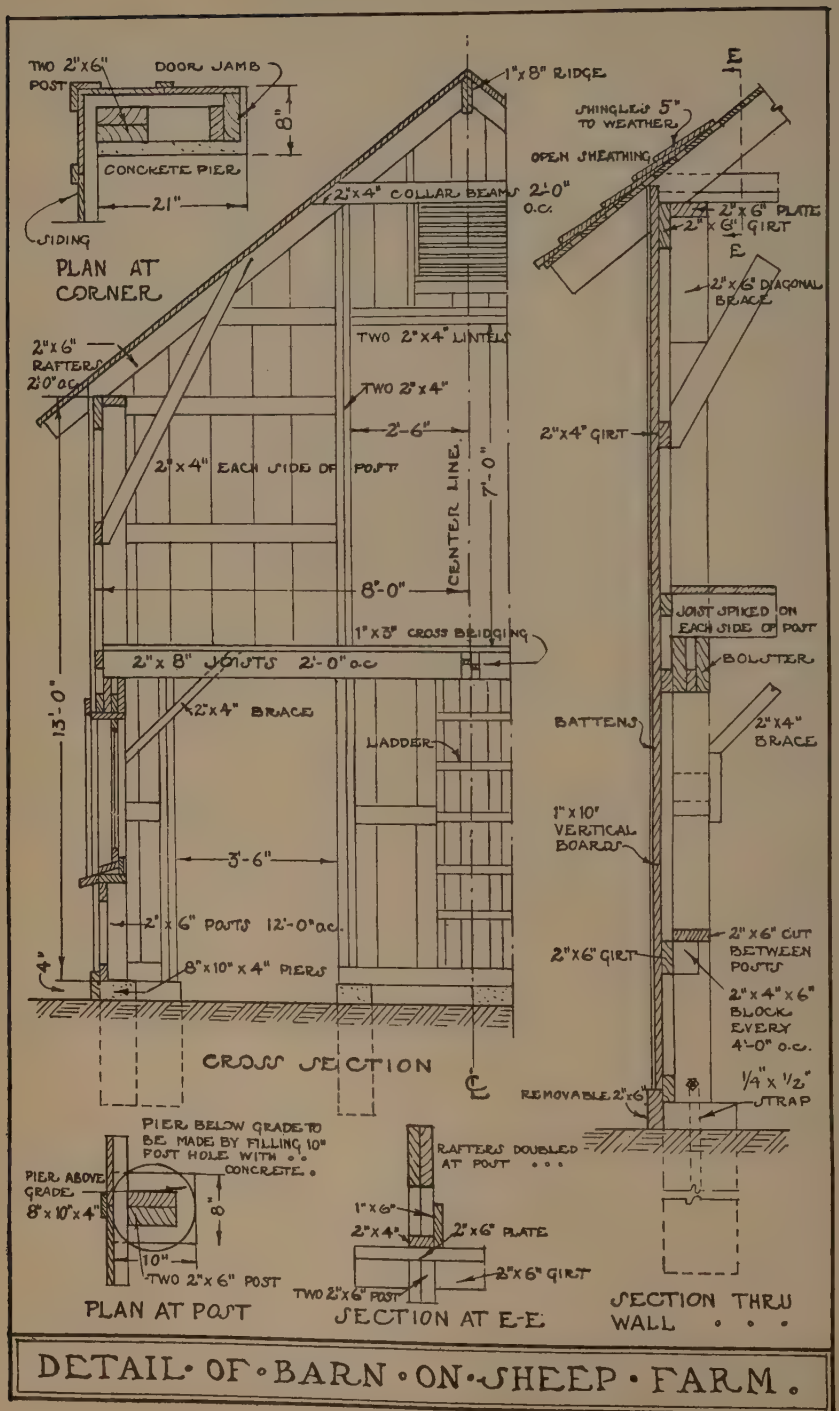
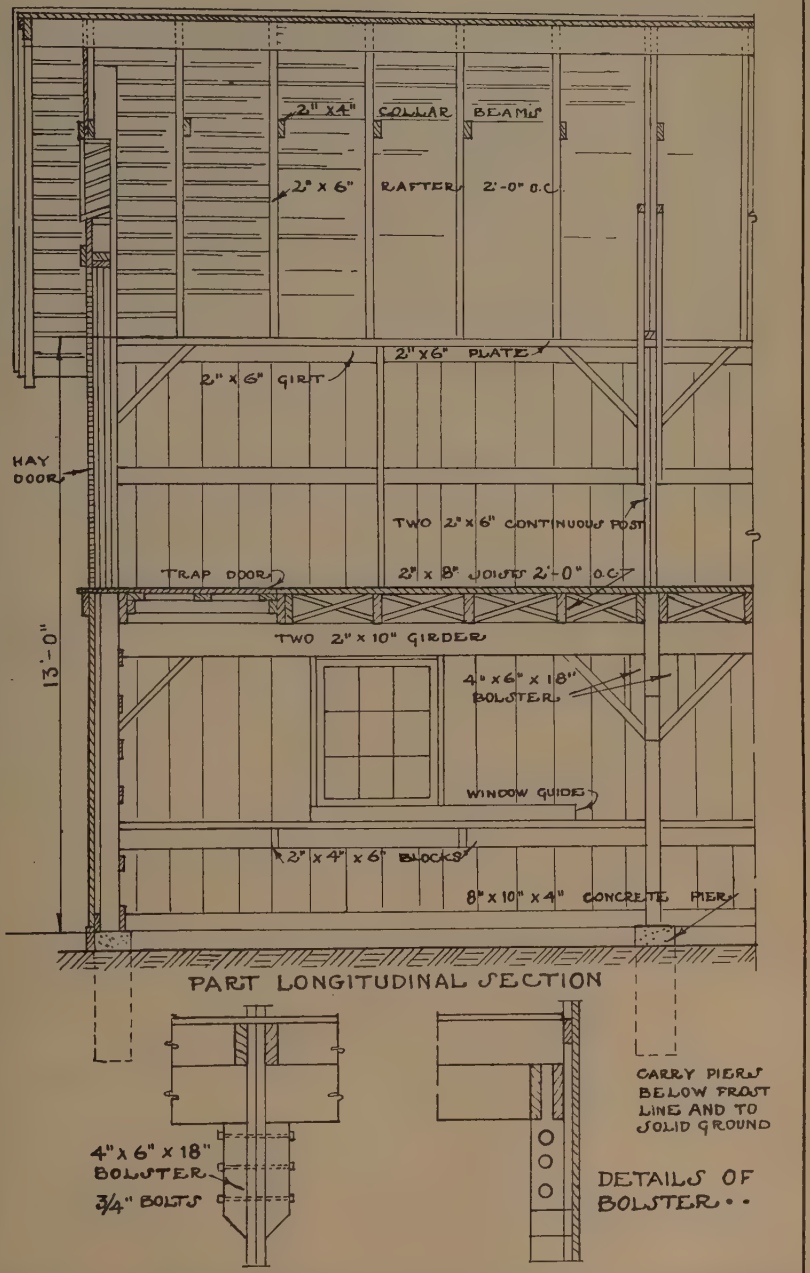
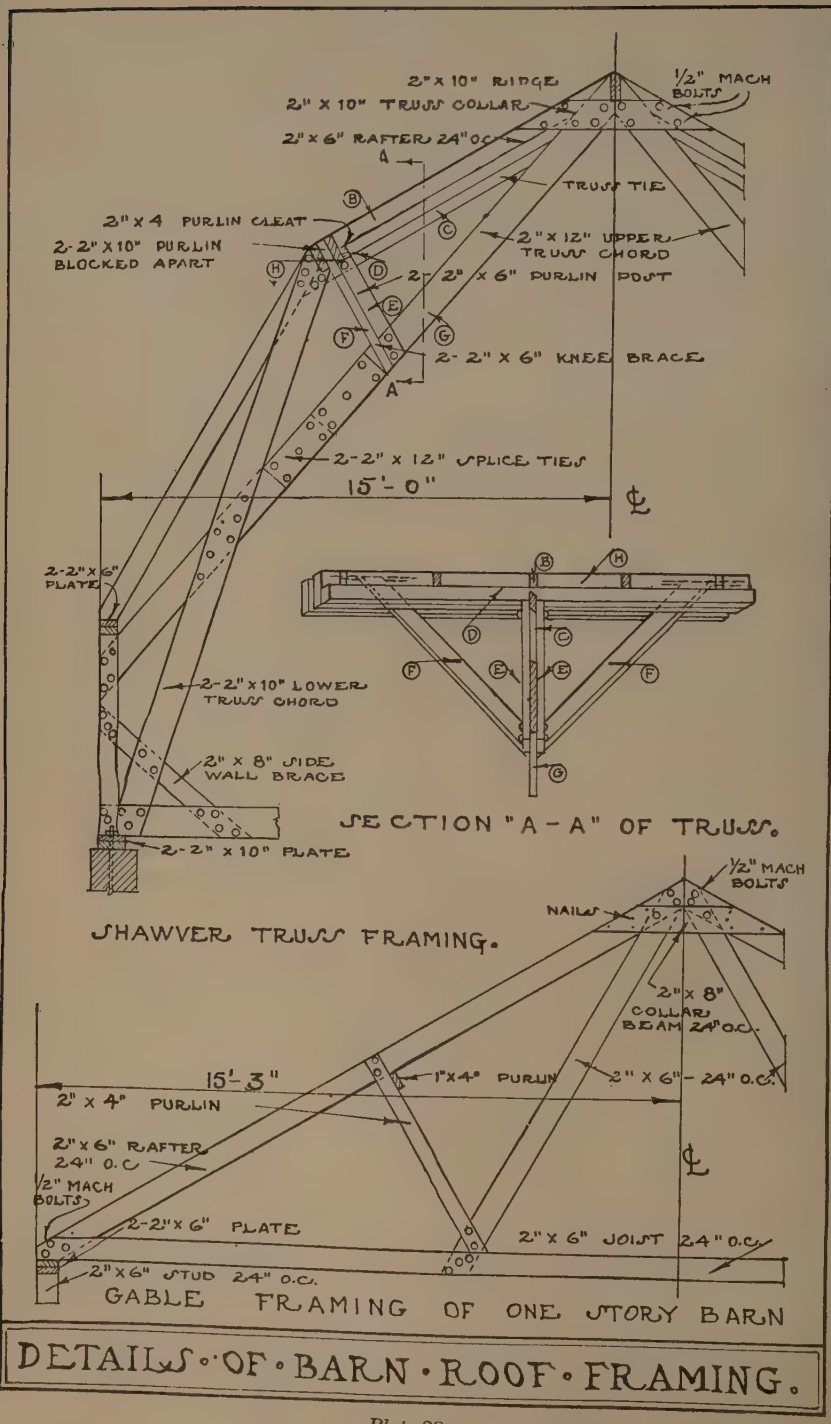

TWO 2"x6" POST
DOOR JAMB
8"
CONCRETE PIER
21"
SIDING
PLAN AT CORNER
1"x8" RIDGE
SHINGLES 5" TO WEATHER
OPEN SHEATHING
2"x4" COLLAR BEAMS 2'-0" O.C.
2"x6" PLATE
2"x6" GIRT
2"x6" DIAGONAL BRACE
2"x6" RAFTERS 2'-0" o.c.
TWO 2"x4" LINTELS
TWO 2"x4"
2'-6"
2"x4" GIRT
2"x4" EACH SIDE OF POST
CENTER LINE
7'-0"
8'-0"
JOIST SPIKED ON EACH SIDE OF POST
1"x3" CROSS BRIDGING
2"x8" JOISTS 2'-0" o.c.
BOLSTER
13'-0"
2"x4" BRACE
LADDER
BATTENS
2"x4" BRACE
1"x10" VERTICAL BOARDS
3'-6"
2"x6" POSTS 12'-0" o.c.
2"x6" CUT BETWEEN POSTS
2"x6" GIRT
4"
8"x10"x4" PIERS
2"x4"x6" BLOCK EVERY 4'-0" o.c.
CROSS SECTION
REMOVABLE 2"x6"
1/4" x 1/2" STRAP
PIER BELOW GRADE TO BE MADE BY FILLING 10" POST HOLE WITH CONCRETE.
RAFTERS DOUBLED AT POST
PIER ABOVE GRADE 8"x10"x4"
8"
10"
TWO 2"x6" POST
1"x6"
2"x4"
2"x6" PLATE
2"x6" GIRT
TWO 2"x6" POST
PLAN AT POST
SECTION AT E-E
SECTION THRU WALL
DETAIL OF BARN ON SHEEP FARM.

Plate 26.


2" X4" COLLAR BEAMS
2" X 6" RAFTER 2'-0" O.C.
2"X6" PLATE
2" X 6" GIRT
HAY DOOR
TWO 2" X 6" CONTINUOUS POST
TRAP DOOR
2" X 8" JOIST 2'-0" O.C.
13'-0"
TWO 2" X 10" GIRDER
4" X 6" X 18" BOLSTER
WINDOW GUIDE
2" X 4" X 6" BLOCKS
8" X 10" X 4" CONCRETE PIER
PART LONGITUDINAL SECTION
4" X 6" X 18" BOLSTER
3/4" BOLTS
CARRY PIERS BELOW FROST LINE AND TO SOLID GROUND
DETAILS OF BOLSTER..

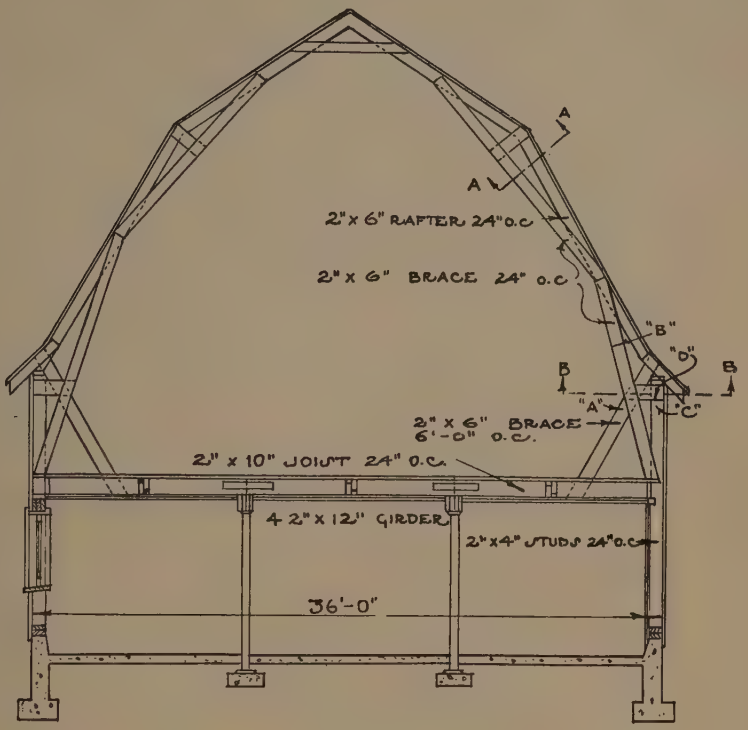
DETAILS · OF · BARN · ON · SHEEP · FARM.

Plate 27.

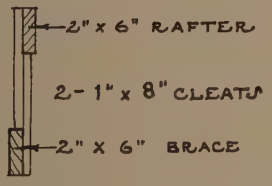

2"x 10" RIDGE
½" MACH BOLTS
2" X 10" TRUSS COLLAR
2" x 6" RAFTER 24" O.C.
TRUSS TIE
3" x 4 PURLIN CLEAT
2-2" X 10" PURLIN BLOCKED APART
2"x 12" UPPER TRUSS CHORD
2-2" x 6" PURLIN POST
2-2" x 6" KNEE BRACE
2-2" x 12" SPLICE TIES
15'-0"
2-2"x 6" PLATE
2-2"x10" LOWER TRUSS CHORD
2" x 8" SIDE WALL BRACE
2-2" x 10" PLATE
SECTION "A-A" OF TRUSS.
SHAWVER TRUSS FRAMING.
½" MACH BOLTS
NAILS
2"x 8" COLLAR BEAM 24" O.C.
15'-3"
2" x 4" PURLIN
1"x4" PURLIN
2" x 6" - 24" O.C.
2"x 6" RAFTER 24" O.C.
½" MACH BOLTS
2-2"x 6" PLATE
2" x 6" JOIST 24" O.C.
2"x 6" STUD 24" O.C.
GABLE FRAMING OF ONE STORY BARN

DETAILS · OF · BARN · ROOF · FRAMING.

Plate 28



CROSS SECTION OF STOCK BARN



SECTION ON "A-A"

SECTION ON "B-B"

DETAILS OF BARN ROOF FRAMING.

Plate 29.

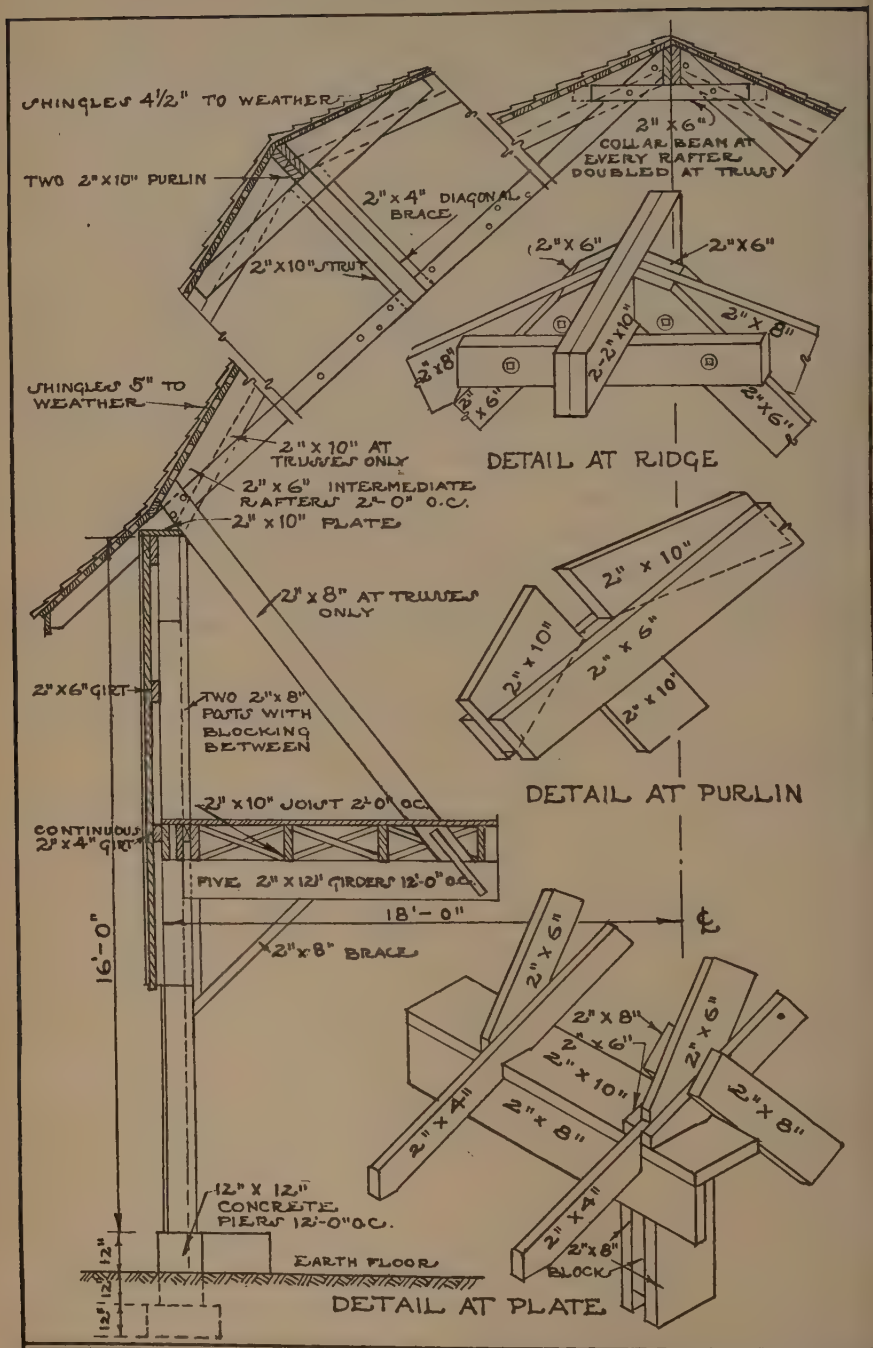

SHINGLES 4½" TO WEATHER
TWO 2"X10" PURLIN
2"x4" DIAGONAL BRACE
2"X10" STRUT
2" X 6"
COLLAR BEAM AT EVERY RAFTER DOUBLED AT TRUSS
2"X6"
2"X6"
2"X8"
2"X10"
2"X8"
2"X6"
2"X6"
DETAIL AT RIDGE
SHINGLES 5" TO WEATHER
2" X 10" AT TRUSSES ONLY
2" X 6" INTERMEDIATE RAFTERS 2'-0" O.C.
2" X 10" PLATE
2" X 8" AT TRUSSES ONLY
2" X 10"
2" X 10"
2" X 6"
2" X 10"
DETAIL AT PURLIN
2"X6" GIRT
TWO 2"x 8" POSTS WITH BLOCKING BETWEEN
2" X 10" JOIST 2'-0" O.C.
CONTINUOUS 2" X 4" GIRT
FIVE 2" X 12" GIRDERS 12'-0" O.C.
18'-0"
16'-0"
2"x 8" BRACE
2" X 6"
2" X 8"
2" X 6"
2" X 6"
2" X 10"
2" X 8"
2" X 8"
2" X 4"
2" X 4"
2" X 8"
BLOCK
12" X 12" CONCRETE PIERS 12'-0" O.C.
EARTH FLOOR
12"
12"
12"
DETAIL AT PLATE
CROSS·SECTION & DETAILS·OF·A·BARN

Plate 30.

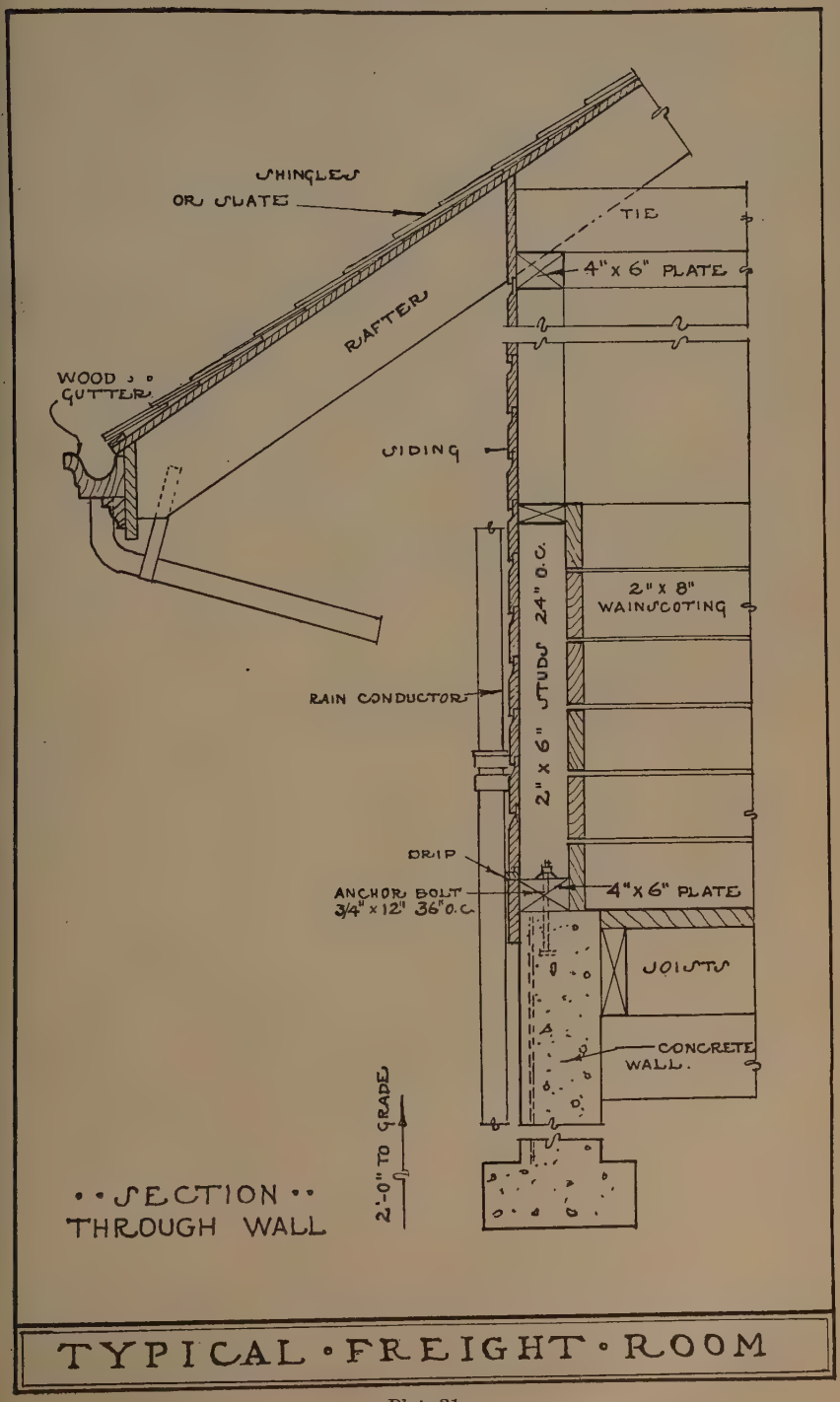
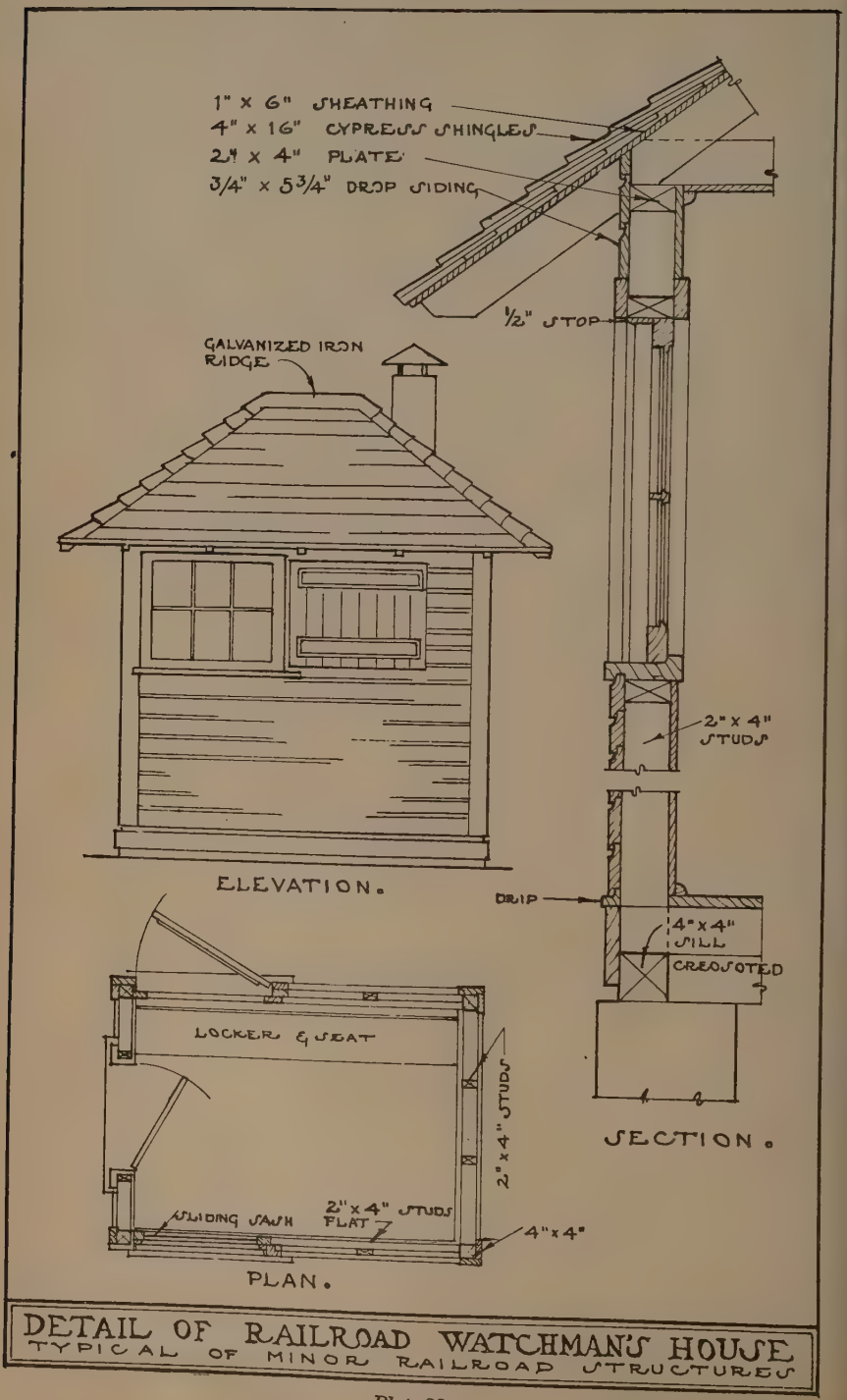

SHINGLES
OR SLATE
TIE
4"x 6" PLATE
RAFTER
WOOD
GUTTER
SIDING
2" x 8"
WAINSCOTING
RAIN CONDUCTOR
2" x 6" STUDS 24" O.C.
DRIP
ANCHOR BOLT
3/4" x 12" 36" O.C.
4"x 6" PLATE
JOISTS
CONCRETE
WALL.
2'-0" TO GRADE
SECTION
THROUGH WALL
TYPICAL • FREIGHT • ROOM

Plate 31.



DETAIL OF RAILROAD WATCHMAN'S HOUSE
TYPICAL OF MINOR RAILROAD STRUCTURES

Plate 32.

Figure 81 illustrates a self-supporting gambrel-roof farm barn under construction, utilizing the braced-rafter type of barn framing.

The poultry-house plan shown in *Plate* 25 was evolved by the University of California in cooperation with the Department of Agriculture for the Pacific Coast and calls for frame construction with the average kinds and grades of lumber available in that territory.

Plate 25 also shows a section of a milk house, with simple roof framing on double plates. The sills are bolted to the masonry every 6 ft.

Plates 26 *and* 27 show details of construction recommended by the United States Department of Agriculture for barns on sheep farms. In these barns the frame is fastened to masonry walls. The bottoms of the posts, which rest on masonry, should be painted with asphalt paint or creosote as protection from moisture and termites. A bolster is used to support the 2 by 10-in. girders. It is well to provide end bearing for bolsters, either by dapping them into the posts or by using keys, so that the entire load will not come on the bolts. *Plate* 28 illustrates details of barn-roof framing designed by the Louden Machinery Company. The trusses shown are usually placed about 12 ft. on centers, with rafters 2 ft. on centers in between. *Plate* 29 also shows the cross-section of a barn developed by the Louden Machinery Company to house stock on the first floor; the hay is stored above. All structural members in this type of barn are 2 in. thick, varying in depth according to the load. The roof is self-supporting and is designed to provide a maximum of storage space with a minimum of material.

Plate 30 shows part of a detailed cross-section of a barn designed by the Department of Agriculture, with roof connection details for the truss.

Plate 31 illustrates the section of a wall in a combination depot on the Central of Georgia Railroad where creosoted lumber is used for the sill, joists and girders; the sill is bolted to the masonry wall, and a wooden gutter is used. In this connection it should be noted that if this station were built in a northern climate, the gutter should be dropped below the roof line to permit snow to slide over without striking it, and the space above the gutter between the ends of rafters should be left open to prevent snow from backing up in the gutter and getting under the shingles.

The details of a watchman's house on the Central of Georgia Railroad, shown in *Plate* 32, are typical of the details of a number of small railroad buildings, many of which are set on pile or post foundations, in that section of the country.

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Voss and Henry, "Architectural Construction," Vol. II, Bk. I. John Wiley & Sons, Inc., New York, 1925–27.

"Recommended Minimum Requirements for Small House Construction," Building Code Committee, *Rept.* U S. Dept. Commerce, Washington, D.C.

Knobloch, Philip G., "Good Practice in Construction." Pencil Points Press, Inc., New York, 1927.

CHAPTER IX

MILLWORK

Millwork (or woodwork, the term in common use today) is generally construed as including all building material made of finished wood and manufactured in millwork plants and planing mills.

In general, a full line of millwork includes complete entrance frames, (*exterior and interior*) inside and outside doors (*both solid and veneered*), window and door frames, windows and sash, louvres and blinds, porch work, mantels, panel work, dining alcoves, stairways and stair material, interroom openings, exterior moldings, interior trim, and jambs. Framing lumber, flooring, ceiling, siding, and furring do not come under the category of millwork.

Millwork differs from cabinetwork in that millwork includes only those forms where machined parts, brought together with the aid of a machine, produce the finished article. Cabinetwork requires a certain amount of high-class hand joinery. It embraces a full line of "permanent furniture," such as bookcases and bookcase material, wall cases and cupboards, china closets, broom closets, kitchen dressers, wall-case ironing boards, dressing tables and cases, linen cases, medicine and bathroom and telephone cabinets. Additional items of cabinetwork are constantly being brought out, as modern home and apartment life demand space saving "built-ins."

Stock and Special Millwork.—Millwork is divided into two general types, or classes: stock millwork and special or detailed millwork. Stock millwork is produced in standardized quantity; detailed millwork, on a particular order.

The quality of stock millwork has been improved with the advent of modern manufacturing methods. Manufacturers are giving more attention to design than ever before, and the public, through campaigns in magazines and newspapers, has developed an apprecation of what good construction and good design mean.

Special millwork, detailed for the individual job, can be made to express whatever effect is desired by the owner and the architect. It is obvious, without stressing the point, that any kind of special millwork costs more to produce than stock millwork.

For example, if a door is made to special detail, as many machine set-ups are required as there are parts to the door. All the initial cost of laying out and of set-ups goes into the charge for the special one-item-at-a-

time design. In mass production, this same cost is divided by the hundreds or thousands run to standard detail by machines that do not require changes except to change for size of door or another design, thus reducing the unit preparatory cost to practical insignificance.

It is decidedly to the advantage of the architect and contractor that the millwork, whether it be stock or special, be produced by a reliable and modern mill.

Fundamentals of Good Millwork.—The three fundamentals of good millwork are:

1. Good architectural design.
2. Sound and lasting construction.
3. Materials of known and dependable quality.

In this day of mass production, and of highly developed manufacturing methods, it would seem that millwork might be obtained by the architect or contractor through the selection of certain designs and the recommendation that "good millwork" be provided. This, however, is not necessarily the case. It is imperative that the quality of the millwork be known to architect and contractor and that the reputation of the mill be good, so as to eliminate even the possibility of getting poor millwork. Unless a mill is equipped to turn out fine millwork and has a name for high-class, dependable, quality work, it is hardly logical to expect excellent millwork, even though the price for it be high enough to warrant choice material.

Poor millwork is often put into high-class homes and buildings, through lack of understanding on the part of architect and contractor. The plans may call for excellent designs, and the specifications may demand good millwork, yet there may be disappointment and regret when the job is finished. The only safeguard against such a condition is for the architect, the contractor, or the owner to know the millwork specified and purchased.

In the case of stock millwork items, manufactured at a distant point, it is not always possible for an architect, contractor, or owner to know the manufacturer; in this case he may depend on the reputation of the local representative.

Regardless of how intelligently millwork may have been specified or purchased, there is an important element which enters into the millwork problem other than its design and manufacture, and that is the proper care of it after it is delivered to the job, while it is being installed, and after it is finished and in use by the occupants of the dwelling or building.

Importance of Proper Drying.—At a moisture content within the fiber-saturation point of a species, wood swells and shrinks with changes in moisture content; this adjustment to surrounding conditions goes on to some extent regardless of the type of filler or finish used but can be controlled within reasonable and practical limits.

The purpose of kiln drying is to remove a certain amount of the moisture naturally present in wood, and which, if allowed to remain, would interfere with its use, particularly from the standpoint of the manufacturer of woodwork. The amount of moisture to be removed depends, of course, on the quantity of moisture present and on the purpose for which the wood is to be used.

Water occurs in wood in two forms—as absorbed water and free water; the former in the cell walls, the latter in the cell cavities. When a piece of wood becomes thoroughly soaked, the cell walls first absorb water until they are thoroughly saturated, then the cell cavities fill up with free water.

As that piece of wood is dried, either in the air or in the kiln-drying process, the free water dries out first, leaving the absorbed water which never can be entirely driven out. Nor is it desirable that it should be. The fiber-saturation point is reached just before the absorbed water begins to be driven out of the cell walls. That is, the cell walls contain all the water they will hold, retaining it until after the free water has been drawn out.

To dry lumber successfully and to know when it has reached the proper dryness, it is essential that the operator be able to determine the amount of moisture in the wood at any time. There are several methods by which the moisture content of wood may be determined, but the one most commonly used involves the cutting of samples, the weighing and drying of the samples, and the establishment of the "oven-dry" weight. The percentage of moisture content of these samples is established by dividing the difference between the original weight and the oven-dry weight by the oven-dry weight, as described in Chap. I (p. 23).

KILN DRYING

The drying of wood is a complex process, and many of its phases are still undetermined. The movement of moisture, however, tends to an even distribution, carrying it from the more moist regions of the wood to the drier ones. This movement within the wood is affected by three controllable external factors—heat, humidity, and air circulation. A constant application of these three factors, in proper proportion, is essential in the successful drying of lumber to the desired moisture content, and, therefore, the regulation of these three factors is the main problem in the successful operation of kiln drying.

Steam is almost universally used for the heating of dry kilns of all types. Complete knowledge of its use is essential to intelligent kiln operation. As the steam (either high or low pressure, depending upon whether or not it is above or below 10 lb. per square inch) circulates through the kiln radiators, the air is heated and the lumber in the kiln is dried accordingly.

Automatic or thermostatic heat controls provide for absolute control of temperature.

Control of Humidity.—The drying capacity of air varies greatly, because the capacity of the air to hold water depends on its temperature. The power of air to dry a substance, therefore, varies with the amount of additional moisture the air can hold before it becomes saturated.

The amount of vapor in the air, expressed as a percentage of the amount held at saturation, is called *relative humidity;* the lower relative humidities represent dry air, and the higher relative humidities represent moist air. At a temperature of 125° F., air can hold a maximum of 40 grains of water per cubic foot. If an atmosphere at that temperature had but 10 grains of water per cubic foot, it would then represent a relative humidity of 25 per cent.

The amount of moisture in the air determines not only the rate of drying but also the extent to which wood will dry. There is a definite balance between the humidity in the air and the moisture content of wood. All kinds of wood, if held long enough in an atmosphere of constant temperature and humidity, will come to the same moisture content. The time required for this adjustment varies with the different species of wood. The relation between humidity in the air and moisture in the wood is important, since it forms the basis of drying schedules and determines the extent to which wood for certain specific uses should be dried.

Since the humidity in the air determines its drying capacity at any given temperature, the control of humidity in the dry kiln is of prime importance. Moisture can be removed from the wood surface only at a drying rate which has been predetermined as practical. If the humidity is too low, the wood will dry too rapidly and will be injured. If the humidity is too high, the drying will be slow and too expensive.

Humidity is measured by an instrument commonly known as a *hygrometer* or a wet- and dry-bulb thermometer. Such instruments are adapted to dry-kiln use and even though called by other names, are the same in principle.

It is easier to increase the humidity in a kiln than to decrease it. Humidity is increased by injecting steam into the kiln chamber. Atmospheric air—usually drier than that in the kiln—is often used for dehumidification, moist air being thrown off through ventilating flues and fresh air being brought in through intake flues.

Moisture may be removed from the air by condensation, the water vapor in the air condensing as it passes over a substance colder than the dew point of the air. Condenser pipes with cold water flowing through them are used for this purpose. Sometimes a refrigeration plant circulating brine through the condenser pipes is used.

Cold-water sprays, the spray temperature being below the dew point of the air, are also used to dehumidify the air. The control of humidity

is more difficult than the control of temperature and requires more exact instruments.

Air Circulation in Kilns.—It is absolutely necessary to have a certain amount of air circulation in a kiln, to convey the heat from the steam coils (or other source) to the lumber and to carry away the evaporated moisture.

The simplest way to produce this circulation is by using chimneys or flues, a natural draft thus being set up by the difference in temperature between the outside air and the air in the kiln.

The air intakes are located at the bottom of the kiln, and the outlets are located along the sides and in the ceiling. The higher the chimneys applied to these outlets the more rapid will be the circulation. Correct circulation may be established either by regulating both the chimney heights and the airtightness of the kiln, or by dampers.

Properly located condensers assist materially in producing circulation and also in reducing humidity, since if air is heated at one point in a confined space, and continuously cooled at another point in that same space, there will be a continuous flow of heated air upward at the first point and of cooled air downward at the second point. This will set up cross-circulation between the two points, the condenser acting as a cooling agent, and the steam coils or radiators supplying the heat.

Fans and blowers and steam jets may be applied to correct or to stimulate this flow of air and establish the correct amount of air circulation.

For a particular drying condition, it is possible to specify temperature and humidity, but the amount of circulation is not so easily specified. Rapid uniform circulation produces faster and more even drying and permits better control of drying conditions than slow, irregular circulation. It becomes increasingly difficult to secure uniformity, however, as the speed of circulation increases. To produce and maintain a high circulation rate increases expenses.

The ventilated type of kiln of low rate of circulation has been in satisfactory operation for years. Constant study both of the specific wood products to be dried, and of the particular kilns used by a given manufacturer, is the most practical way of learning the best methods to use in the control of air circulation.

There are a number of ways in which the air circulation may be tested; and tests are constantly carried on by the woodwork manufacturer interested in seeing that his product is made and delivered under the most advantageous conditions from the standpoint of the ultimate user.

STRESSES SET UP IN THE DRYING PROCESS

The moisture in wood tends to equalize itself by flowing to areas of lesser moisture. By removing some of the moisture from the surface itself, it is possible to start a movement of moisture from the inside toward the surface of a piece of wood of uniform moisture content.

As the drying of green wood progresses, the quantity of free water in the cells gradually diminishes. At first, the cells near the surface lose all their free water, the fibers themselves remaining saturated.

It is at this point that changes in the properties of the wood begin to take place, since wood begins to shrink as soon as it begins to lose moisture, starting with the fiber saturation point and continuing to shrink as long as moisture is drawn from it.

The shrinkage is practically proportional to the amount of drying below the fiber-saturation point but is not uniform in all directions.

Longitudinal shrinkage parallel to the length of the board, or with the grain, is practically nothing and can be eliminated from consideration. The tangential shrinkage, parallel to the circumference, or in a horizontal direction in the standing tree, is usually one and one-half to three times as great as the radial shrinkage, which is perpendicular to the rings and to the tangential direction. Shrinkage is proportionate to density or weight of wood, the heavier woods shrinking more than the lighter ones, as a rule. Shrinkage is accompanied by a hardening, a reduction of plasticity, and a reduction in the rate at which the moisture transfuses through the wood. These changes are accompanied by important changes in mechanical properties. The wood becomes stronger under such stresses as bending, tension, and compression. The increases in strength as the wood is dried from fiber-saturation point to zero moisture may be as much as several hundred per cent of the corresponding value in the green wood.

DEFECTS FROM DRYING

Defects from drying are due to uneven shrinkage and the attendant stresses set up thereby. The major defects are case hardening, checking, honeycombing, warping, and collapse.

Case hardening results from too rapid drying; the outer surfaces of the wood pass the fiber-saturation point and shrink, squeezing together all of the green wood inside, since that wood has not yet reached the fiber-saturation point. This results in the surface layers' creating a state of compression inside the piece and in themselves a state of tension. As the drying process continues, the outside layers (now in tension) become sufficient in number and thickness to withstand the compression action of the inner layers below them; the exterior layers are then "set."

Further drying produces a tension in the interior layers, which reverses the force in the outer layers, putting them into compression. This condition is known generally as *case hardening.*

As this case-hardening process starts, if the strength of the wood in tension across the grain is not sufficient to resist the tensile stresses in the surface layers, it will tear open, forming surface checks. Likewise, if the inner layers are not strong enough to resist the tension placed upon them during the latter stages, they will rupture, causing what is generally called

honeycomb. Checks and honeycomb more often run radially than tangentially.

Warping and twisting are due to uneven shrinkage caused by spiral or interlocked grain or by the difference between sapwood and heartwood in longitudinal shrinkage or by various other irregularities in structure and in drying processes.

One seasoning defect is the actual collapse of rows of cells, occurring in a few species such as redwood, western red cedar, swamp oak, and red gum. This is a common occurrence but can be eliminated through the use of low temperatures at the beginning of the kiln-drying process.

DETERMINING EXISTING STRESSES

The detection of the stresses which cause the various defects enumerated above is one of the most important of the kiln operator's duties, requiring skill, close application, and education. To determine these stresses, test pieces are taken from the average run of stock to be dried and slotted, as illustrated in Fig. 82. These sections should not be taken nearer than 2 ft. from the end of an average board, and they should be about 1 in. long in the direction of the grain.

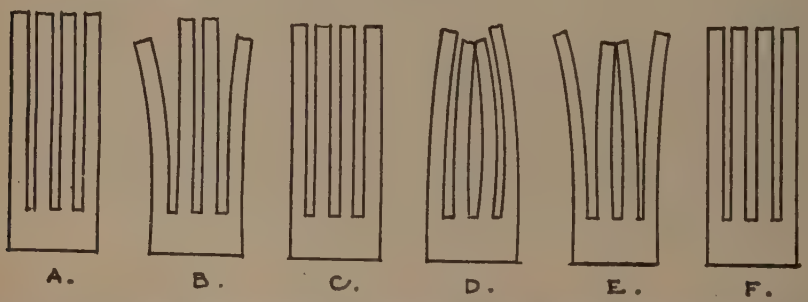


FIG. 82.—Typical stress sections: *A* represents a green board; *B* shows tension in the surface typical of early stages in the drying; *C* shows that drying has progressed farther and the shrinkage of the interior has balanced that of the surface; *D* shows typical case-hardening; *E* reveals slight reversal of stresses by treatment to relieve case hardening; *F* is the finished board free from stresses. The changes in the length of the prongs has been slightly exaggerated.

After these sections are slotted, the action of the various test pieces thus developed determines the character of the tension in the piece. If the outer prongs turn out, it indicates tension in the outer layers. If they turn in, it indicates compression. The compression side of each prong immediately stretches, and the tension side immediately contracts. The side originally in tension will become concave, and the one originally in compression will become convex. The amount and distribution of moisture content, therefore, can be judged by the relative bending of the several prongs.

When the prongs turn inward, the judgment cannot be so definite, since these prongs interfere with each other; but with experience it should be easy to determine just how thick or thin to cut them so that they may operate without interference.

Test sections of this character should be taken from time to time as the kiln-drying processes go on, and such corrective remedies should be applied as are indicated by the study of these test sections. Naturally, the more nearly dry the stock is when the test sections are cut the more reliable they become as indicators.

It is impossible to lay down hard-and-fast rules for the steaming and humidity treatment. Usually, a study of the finished product and its performance, carried back to the kiln operation, is the best method of absolutely solving the individual problem within a given industry. The degree of treatment given is, of course, determined by the condition of the stock at the time it goes into the kiln. The final standard to be applied by any industry can best be arrived at by experience, and the value of the kiln-drying expert is in his ability to take stock in varying conditions and deliver it for manufacture in the required standard condition.

After the material is made ready for manufacture, a great deal of resawing is done, which makes it absolutely essential that case hardening be removed. Relief from case hardening is necessary in all woods, even in those most easily kiln dried, because in the manufacture of woodwork generally, even though a piece may not be resawed, the outside of it will be worked in some fashion. The wood removed is always taken from the outside of the piece, so that, if these stresses and strains are not relieved, they become active and eventually distort the final profile.

DRYING PERIODS

Drying periods, of course, vary greatly according to the length of time it takes to pass the lumber through the kiln. Hardwood, after being sawed from the log, should be air dried on sticks from 60 days to 6 months, before it is ready for the kilns. After that, 1 in.-hardwood stock, for example, from the time it is semidry to the time when a 5 per cent moisture content is obtained, requires from 14 days roughly as a minimum to as high as, perhaps, 60 days as a maximum, depending upon the stock itself and the character of the kilns used.

The degree of moisture (water) in a given piece of wood, usually referred to as *moisture content*, is determined by the percentage by weight which the water in the wood bears to the weight of the wood itself. Keeping the meaning of this term in mind, thoroughly kiln-dried lumber has a moisture content usually ranging from 3 to 8 per cent, while in the average air-dried lumber, the moisture content runs from 12 to 20 per cent.

Lumber dried to a moisture content of 3 per cent, or less, is comparatively brittle and in such condition is very apt to check or split while

being handled in a perfectly normal manner; while, if this same lumber has been dried to a moisture content of not less than 5 per cent, there would not be this brittleness which develops as a direct result of the elimination of so much moisture from the wood.

It has been proved by numerous tests that various kinds of woods, when kiln dried to a moisture content of as low as 2 per cent, will, during a relatively few damp, muggy days and while under cover and protected against rain, absorb enough moisture from the atmosphere to bring the moisture content back to as much as 8 per cent. Most lumber, when kiln dried to a moisture content of below 4 per cent, will absorb enough moisture during a few days, even in clear weather, to bring the moisture content back to at least 6 per cent.

Since nearly all lumber, handled under average conditions, will absorb from normal atmosphere sufficient moisture to bring it up to at least 6 per cent moisture content, it is quite clear that it would not be good practice to dry it much below that point when putting it through the kiln-drying process. A leading woodwork manufacturer makes it standard practice to kiln dry all lumber down to a 5 per cent moisture content and then put it in storage sheds to temper for from 2 to 8 weeks. During this tempering process, the lumber will take on sufficient moisture from the atmosphere to bring the moisture content up to from 6 to 7 per cent, depending on the species of the lumber.

Six Per Cent Moisture Content.—Scientifically produced woodwork, therefore, should be made from lumber kiln dried to a moisture content of as near 6 per cent as the manufacturer can keep it. This insures against any abnormal amount of stress, or strain, through the normal swelling during the summer season when the doors and windows of buildings are open and there is naturally a greater amount of humidity in the atmosphere. At this moisture content there should be no excessive shrinkage in winter, when the air is artificially heated, unless, as will be explained later on, the air lacks a suitable amount of moisture.

Any change in the moisture content of lumber will cause a shrinking or swelling, depending on whether it is taking on or giving off moisture from the atmosphere. This continual shrinking or swelling is commonly spoken of as the *working* of wood and applies to every known wood to a greater or lesser extent; it is a factor of extreme importance.

Since it will probably be conceded that, for the reasons just given, doors and other woodwork should be made from wood with a moisture content of from 6 to 7 per cent, it logically follows that during the cold winter season, the moisture content of the atmosphere in a building should be looked after. If making wookwork from lumber containing not less than 6 per cent moisture guards against trouble from swelling during the summer season, when there is no necessity for artificial heat and normal summer conditions prevail, then it quite obviously should be the responsi-

bility of the one in authority in any building or home to see that this produced woodwork is not damaged, oftentimes beyond repair, by the introduction of artificial heat during the winter season without maintaining an adequate amount of moisture in the air.

If the moisture (humidity) in the atmosphere of a room is only about half of what it should be, the effect upon the woodwork is very bad. The shrinking, warping, and checking, which almost invariably follow the drying out of the woodwork to a point considerably below the 6 or 7 per cent which it contained when it was machined and put into the building, is a perfectly natural and logical development. Assuming for the woodwork an average year-round moisture content of from 6 to 7 per cent, then difficulties will surely develop during the winter season when artificial heat is applied, if it is not accompanied by an adequate amount of moisture.

It is not uncommon for artificial heat without adequate moisture to dry out woodwork during the winter to a moisture content of close to 2 per cent, and perhaps even lower, although no records exist to prove anything below 2 per cent. The shrinking of parts due to this "baking" process sets up a series of stresses and strains, which not only seriously affect the fibers of the wood but also sometimes strain the glue joints to the point of complete rupture.

MOISTURE CONTROL IN BUILDINGS IMPORTANT

The surest way to avoid considerable trouble with woodwork is to provide for the artificial introduction of moisture into the atmosphere of buildings when heat is needed during the colder portion of the year. It is probable that on account of lack of knowledge along this line, average office buildings and residences, at least through the northern half of the United States, have an atmospheric humidity throughout the winter months so low that it dries out the woodwork far below the 6 per cent which it is presumed to have contained when it was installed. When this abnormal and really unnecessary shrinkage of parts develops because of the "baking" process, the owner, lacking knowledge on the subject, is natually inclined to blame the woodwork producer.

The proper room temperature in a residence or office building, when there is an ample amount of humidity (moisture) in the air, is from 68 to 70° F. The relative humidity, in order to make a proper balance, varies not only with the actual amount of moisture in the air but also according to the differing room temperatures and is determined by a process which need not here be explained. This relative humidity at the different temperatures is indicated in percentage figures; and charts to determine the proper relative humidity at different room temperatures are available

at several sources, including the Forest Products Laboratory, Madison, Wisconsin.

The chart shown (Fig. 83) was produced by a leading woodwork manufacturer as a means of insuring better care of the product after it had left the plant and become a part of the finished structure. The method of using this chart is completely described thereon. Bear in mind that the ideal condition referred to on p. 352 may be produced by so handling humidity that the difference, as evidenced by the wet and dry thermometer bulbs, amounts to 10. This difference at a room temperature of 70° produces a relative humidity of 55 per cent.

The maintenance of one or more hygrometers at advantageous points throughout a structure during the process of construction, is a matter of interest to manufacturers, builders and architects, because, by keeping the wet- and dry-bulb difference at 10, a constant relative humidity throughout the structure is insured. It will, of course, be impossible to maintain this condition exactly, but the use of the hygrometer and the care taken to regulate the relative humidity will result in a much more satisfactory job of woodwork and interior trim.

Up to the time the heating system is installed in the structure, this condition of relative humidity can best be regulated through ventilation. Later, the heating system, plus the evaporation of water through its aid, makes the holding of a fairly constant relative humidity a simple matter.

While it is not absolutely essential to watch this condition prior to the installation of the woodwork, it is very much worthwhile.

Structural lumber, such as studding, is often exposed to the elements and so thoroughly saturated with water that, especially in a wet season, it will dry out very slowly after having been covered with the plaster, and the shrinkage which follows may be part of the cause of trouble common to woodwork. It is desirable, therefore, that the effort to control the relative humidity be started as soon as the structure is enclosed.

A specific illustration has to do with a method of handling closet doors. If the door to a closet is hung before the plaster is thoroughly dried out, it is subject to worse conditions than even a front exterior door, as measured by the difference of relative humidity on either side of that door. There is relatively a small volume of air, measured in cubic feet, contained within a closet. That volume, in a closet whose walls and ceiling are covered with damp plaster, very quickly comes to the saturation point when the closet door is closed. On the other side of the door, the air may often be close to absolute dryness. Regardless of construction, character of wood, or method of finishing, the wood in such a door will "work."

To eliminate this condition, it would be well to open all closet doors 90° as soon as they are hung and securely fasten them in this position

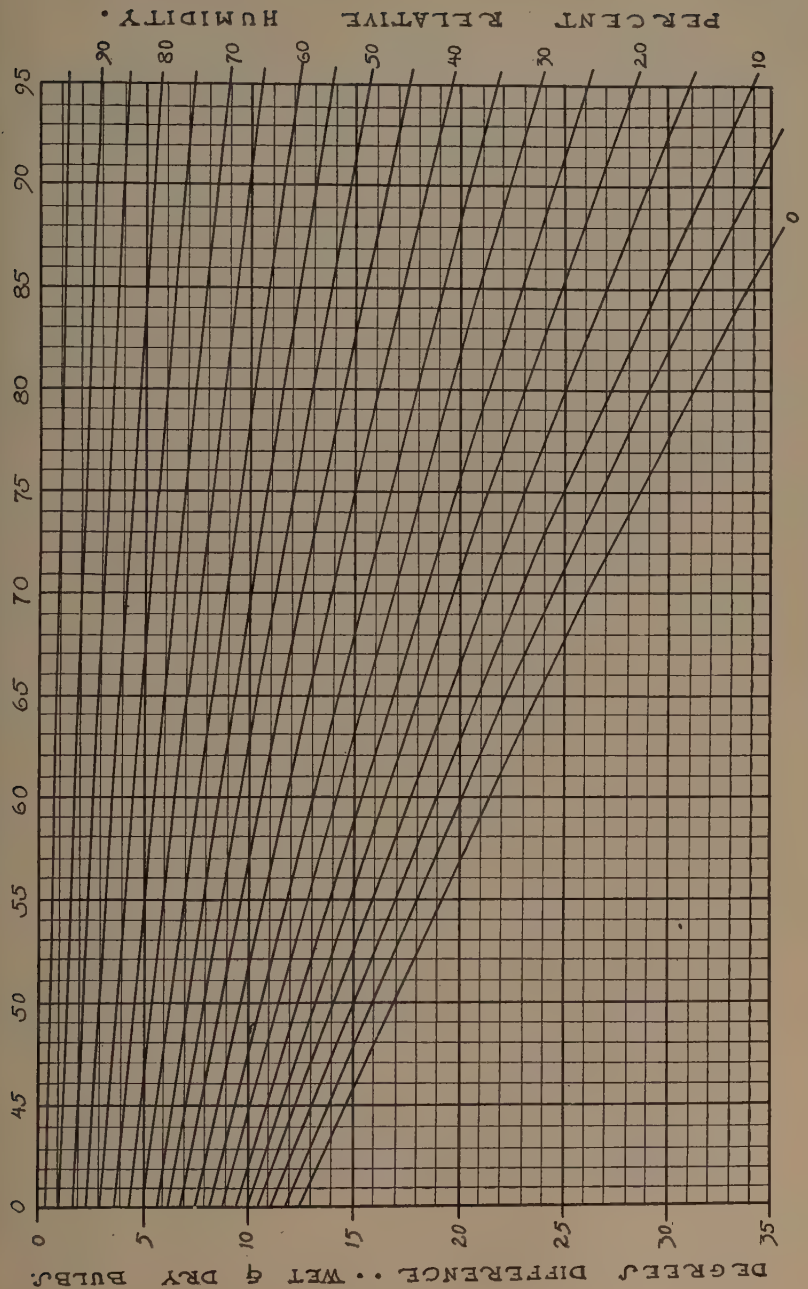


Fig. 83.—Relative humidity chart.

To use: First. Locate room temperature and run down vertical line.
Second. Locate degrees difference and run horizontally across sheet.
Third. Where above lines meet follow curved line to right and read percentage of humidity.

by tacking small blocks to the subflooring. This will tend to distribute the humidity evenly.

In common practice, the trim and doors are erected and hung just as soon as possible after the plaster is on, and, particularly in cheap work, little thought is given to this situation. It is the cause of 90 per cent of the woodwork troubles; and is not a fault of the woodwork but is the result, rather, of improper handling.

PROPER ROOM HUMIDITY

The proper or ideal relative humidity for a room temperature of 68 to 70° would be about 55 per cent. The relative humidity of the air in the average residence and office building is substantially below 30 per cent, and is frequently less than 20 per cent.

The reason that a room temperature of 70°, with a relative humidity of 55 per cent, is spoken of as the *proper* atmospheric condition, is because it comes close to the atmospheric condition and moisture content of a bright, clear, summer day. From the standpoint of the health of the occupants of the building, and the most efficient use of the fuel consumed, as well as the welfare of the furniture and woodwork, it should at least approach this percentage during the winter season. A relative humidity of substantially less than 30 per cent should be a just cause for alarm on the part of the owner.

The home owners of former generations may have been wiser than we are, for they usually had their steaming kettles on the fire, and the water pan in connection with the old "base burner" was always kept full. They doubtless realized that this vapor (humidity) in the air helped to make the room feel more comfortable at a given temperature and also served as a safeguard against throat troubles and colds. In those days, the question of fuel economy was of less importance, but in these days when fuel is high, one should not overlook the fact that there is a real saving in fuel when a proper amount of humidity is present.

It is generally conceded by the various authorities on the subject that the average person feels more comfortable with a room temperature of about 68°, when the atmosphere contains an ample amount of humidity, than he does at a temperature of from 72 to 75° when the air is entirely too dry and becomes a menace to the health of the occupants. During the winter when the air in any building shows a relative humidity of not over 20 per cent, indicating that there is substantially less than one-half enough water in suspension, the "bake-oven" condition is being approached.

Wood is continually taking on and giving off moisture, depending upon the moisture content of the atmosphere with which it comes in contact. If the air in a room has an extremely low relative humidity

(almost no moisture), then it is clear that the moisture in the wood will be evaporated, since the moisture content of the wood and the air in the room will tend to balance. At a relative humidity approaching 40 per cent, evaporation should not take place to such an extent as to bring the moisture content of the woodwork below the 6 per cent which it contained at the time it was made. It has previously been made clear that if the moisture content does not go down, the wood will not shrink; it follows that to avoid excessive shrinking in winter, the moisture in suspension in the air should be kept at a point high enough to prevent the moisture in the wood from too great evaporation.

Woodwork in New Buildings.—There is almost if not quite as much chance for trouble when new woodwork is placed in a freshly plastered or otherwise unseasoned building as when it is placed in a finished and occupied building. If not properly ventilated, a new building will throw off enough moisture from partly seasoned lumber and freshly plastered walls to bring the air in the building close to the saturation point. Many cases have been observed where the relative humidity in such a building has risen to 90 per cent or more and continued at this high point for a number of days. Since the moisture in the wood and in the air tend to correspond, such an atmospheric condition would cause an abnormal swelling of the wood. Fully as much stress on the fibers of the wood, and on the glue joints, would follow this as follows the baking process, only it would be the other extreme—excessive swelling instead of excessive shrinking. This abnormal condition may be guarded against by proper ventilation.

A common occurrence in new buildings is for the relative humidity to be very high, in the neighborhood of 90 per cent, when the moisture is being drawn out of the plaster and lumber, and then, within a relatively few days, to have it become extremely low. This must be expected in new buildings where no thought is given to the matter of humidity, and many cases are on record where within a period of 2 weeks the relative humidity of a set of living rooms has gone from more than 90 per cent down to less than 20 per cent. This means that for a period of several days the parts that made up the woodwork had swelled very noticeably, because of the excessive moisture and then, almost immediately following, had shrunk to nearly their minimum size. In many of such cases the damage through cracking, checking, and even rupture of the glue joints is almost beyond repair. In view of the foregoing, it would be well worthwhile to use the hygrometer to determine the relative humidity of the atmosphere.

Veneered doors and all other kinds of interior woodwork, when produced under present approved conditions, should show no particular effect from the slight shrinking and swelling of the wood which will naturally occur through normal changes in atmospheric conditions.

However, woodwork, of the very highest type, manufactured under the most approved conditions, cannot stand up under circumstances which are distinctly unfavorable, either from the standpoint of excessive humidity, as in new buildings, or where the moisture in the atmosphere is entirely inadequate.

Humidity Control.—It is not an easy matter to lay down definite correction rules, because, owing to the general lack of knowledge as to the need for facilities to improve atmospheric moisture content, there are as yet only a limited number of devices on the market to correct this trouble.

The apparatus to be installed for a common hot-air, direct-heat unit is comparatively simple and should be inexpensive. All that is needed is water in a pan of proper capacity placed above the dome of the furnace, so that it can be evaporated by the furnace heat and passed directly up into the rooms above through the hot-air pipes. Such an installation should evaporate something like 10 gal. of water in 24 hours, in average cold weather, and under certain conditions in especially large residences, and in severe winter, it might approach twice this quantity.

With hot-water-, steam-, or vapor-heating systems, the easiest method is to have water pans, sometimes called *humidifiers*, placed either on the side or on the top of the radiators. About the only disadvantage of these is the nuisance of filling them at least once a day; in the case of the water pan over the furnace in the direct-heat plant, the process may be made automatic.

With vapor heat, where the radiators are cold a part of the time while the room temperature is up to the required point, there is usually an inadequate water evaporation, except at times when the heating unit must be crowded in order to keep the room temperature at the proper level, and the radiators are consequently hot all of the time. When steam- or vapor-heating systems are used, experts along this line recommend a water pan on top of the heating unit in the basement, over which air from outside is passed. As the cold outside air passes over the surface of the heated water in the pan, it is warmed and takes up considerable moisture; and when conducted through one or more pipes into the rooms above it usually gives the desired results. This method can also be made practically automatic, and while somewhat more expensive, it is considered much more satisfactory than small receptacles placed on the radiators.

Mechanical Humidifiers.—There are a number of mechanical humidifiers now available, which will automatically maintain proper humidity under varying conditions.

The installation and operation of some of them is quite expensive, but all are unquestionably worth their cost when measured by results.

STORAGE OF MILLWORK BEFORE DELIVERY

In order to reduce the chance for trouble, certain precautions should be taken by those whose duty it is to store woodwork in warehouses pending later delivery to the consumer.

The storage of woodwork against outer walls should be avoided, for without ample circulation of air, the dampness in connection with extreme cold of winter may cause trouble. Piling too close to outside walls may be a cause for trouble in spring and summer, especially when the direct rays of the sun strike the unfinished wood. Lack of care along these lines will result in the raising of the grain of the wood, and if excessive dampness is present when woodwork is in storage, more serious difficulties may develop. Raised grain on the faces of woodwork is in itself not serious, but it does detract from its appearance. A few moments spent in hand-sanding before delivery will bring the wood back to its normal appearance and fully correct what might be regarded by the uninformed customer as a fairly serious defect, while in simple fact it is but a natural result of storage in a warehouse somewhat too damp.

UNEVEN COATINGS ON WOOD CAUSE WARPING

During the installation of woodwork, coatings of equal moisture resistance should be applied to all surfaces, if they are to be kept as free as possible from warp under changing atmospheric conditions. This is important and should always be required.

No coating entirely prevents woodwork from picking up or giving off moisture and either swelling or shrinking under varying atmospheric conditions. Any moisture-resistant finish merely decreases the rate at which the moisture change in wood takes place; the higher the grade and the more coats applied the lower will be the moisture change.

Unequal coatings on opposite surfaces of woodwork cause unequal rates of change in moisture content, and result in unequal shrinkage on the two sides of the piece which makes that piece tend to cup or twist.

Coatings for the backs or unseen portions of woodwork can be applied in one or two coats, depending on the moisture resistance required, which will practically equal the moisture resistance of the surface coating. Recommendations covering suitable coatings of this type can be secured from the Forest Products Laboratory, United States Forest Service, Madison, Wisconsin. Paint information of a thoroughly practical nature can be obtained from any large paint manufacturer.

When at all practicable, the painter should apply a suitable priming coat to all woodwork before it is put into place in the building. The backs, as well as the faces, of casing, flooring, and panelwork should be covered, partially to close the pores of the wood, so that there will be a minimum effect from either too much or too little moisture.

COMMON WOODS USED

The materials used in the manufacture of woodwork generally divide themselves into the soft- and the hardwood groups. In the former, the pines are most common, and in the latter, birch, oak, and gum perhaps more than make up the majority of the woods used. From time to time, a tendency to specialize in certain imported woods shows itself, but the total amount of distribution secured on any of these products is relatively insignificant as compared with the distribution of the species enumerated above.

The oaks and birches are adapted to certain designs of doors, trim, and other woodwork forms, particularly stair material, where it is necessary to carry out more or less elaborate design and to supply great hardness or strength and interesting finished surfaces. As an example, the use of oak in English work is very much in point.

The soft woods combine easy working, high-grade painting surfaces, and low cost.

The use of gum has increased, particularly where panels are used. The two kinds of lumber sold as sap gum and red gum respectively are totally different in quality and appearance, although both varieties are cut from the same tree. Sap gum is cut from the outside rings or sapwood, and red gum from the center or heartwood of the red-gum tree. Sap gum is without figure, of dense texture, and is, therefore, generally used for enameled or painted finish. It takes stain well but lacks beauty or variety. Sap gum has a tendency toward warping and twisting, which is difficult to overcome except with the most carefully controlled kiln-drying and handling at the building.

Commercial red gum is cut into plain sawed or quarter sawed veneers which, according to the pattern of the log, are classified as either figured or plain. Red gum is used extensively to imitate walnut and mahogany. The plain, unfigured red gum is used in solid sections as trim but does not have the same tendency toward warping and twisting that sap gum has. Plain red gum is finished naturally, or stained or enameled.

Douglas fir and southern pine have been available for a number of years in quantity production and have been used extensively in many types of construction. These woods may be used for high-class stained or natural finish, provided they are carefully selected or properly prepared in order to equalize the penetration of the stain or natural finish.

MOLDS AND STAINS

Since any blemish would destroy the beauty of the grain of the wood, bright, clean, stain-free stock is highly desirable for any use requiring a natural finish; but for purposes where the wood is to be covered, stained or painted, there is no reason for discriminating against blue-stained

stock, if it is free from decay. The following list of uses for blue-stained material can be applied under restrictions, as stated on page 191, and according to the best judgment, in each case. As applied to millwork, the list is as follows:

Casing and base, core stock, doors, finish, paneling, stair rail and balusters, sash, window screens and door screens, shelving, stair treads and risers.

Blue-stain fungi cause stains deeper in the wood than ordinary mold, and they cannot be surfaced off. This is one way of determining whether the stain is blue fungi stain or mold. Since the presence of blue-stain fungi does not represent an actual defect, a more general dissemination of information on this point will result in greater use of blue-stained material. Detrimental molds commonly found on sapwood and characterized by cottony or downy growths of various colors are sometimes powdery. Some of these molds cause no direct staining of the wood but produce blemishes due to their variously colored surface growth. These blemishes can readily be planed off and, in some cases, brushed off.

AMERICAN LUMBER STANDARDS

Through general conferences of representatives of manufacturers, distributors, wholesalers, retailers, and users of lumber, including representatives of architects, engineers, and general contractors, held during the past 5 or 6 years, the United States Department of Commerce, through its Bureau of Standards, has recommended that recognized classifications, nomenclature, basic grades, sizes, grade marking, and inspection of lumber be established according to American Lumber Standards.

Reference to Chapter II will give the interested architect or builder detailed information which is far too voluminous to incorporate in this chapter.

Certain provisions, however, as they apply to millwork, are reproduced here and cover the salient and necessary points.

Factory or shop lumber is that lumber which is to be cut up for use in a further manufacture. It is graded on the basis of the percentage of the area which will produce a limited number of cuttings of a specified or given minimum size and quality.

Some few grades, which, according to American Lumber Standards, are classified as yard lumber, find a place in the manufacture of millwork. These grades are found under "select," as distinguished from "common" lumber in the table given on p. 61.

Select lumber is that which is generally clear, containing defects limited both as to size and number, is smoothly finished, and is suitable for use, as a whole, for finishing purposes or other cases in which large,

clear pieces are required. Two general classes of select lumber are recognized, the first of which is suitable for natural finish, and the second of which permits similar defects and, in addition, blemishes of somewhat greater extent than those of the first class but of a type which can be covered with paint. Select lumber is graded as A, B, C, and D. In the table below, in which thicknesses apply to all widths, and widths to all thicknesses, are shown the size board measure, the exact dressed dimensions, and the maximum size of molded forms, which can be made from the corresponding piece of lumber.

More will be said later as to the possibilities this table holds in connection with architectural design, based on the economical practices of lumber usage.

FINISH LUMBER—SOFTWOODS

Size, board measure		Dressed dimensions			
Thickness, inches	Width, inches	Standard thickness, inches	Maximum possible machine-finish thickness, inches	Standard width, inches	Maximum possible machine-finish width, inches
...	..	.....	.....	2⅝	2 1 9/32
...	..	.....	.....	3⅝	3 1 9/32
...	..	.....	.....	4⅝	4 1 9/32
...	..	.....	.....	5⅝	5 1 9/32
1	7	25/32	¾	6½	6 1 5/32
1¼	8	1 1/16	1 3/32	7¼	7 3/32
1½	9	1 5/16	1 9/32	8¼	8 3/32
1¾	10	1 7/16	1 13/32	9¼	9 3/32
2	11	1⅝	1 19/32	10¼	10 3/32
2½	12	2⅛	2 3/32	11¼	11 3/32
3	..	2⅝	2 19/32		

NOTE.—Standard industrial thickness 2 6/32- and 1¾-in. can be secured in addition to standard yard thicknesses shown above for 1- and 2-in. size board measure, at extra cost.

The sizes most commonly used by mills are the sizes nominally known as 1, 1¼, and 1½-in. thicknesses board measure, as shown above in the first column.

The remainder of the sizes are available as finish lumber but are seldom used, cuttings from shop lumber being more generally employed, because the vast bulk of mill production is developed from shop lumber. All grades of finish lumber are used in mill practice, although the grades most extensively used are C and D. They are divided as follows:

Those suitable for natural finishes:

Grade A practically free from defects.

Grade B allows a few small defects or blemishes.

Those suitable for paint finishes:

Grade C allows a limited number of small defects or blemishes that can be covered with paint.

Grade D allows any number of defects or blemishes which do not detract from the finished appearance, especially when painted.

The great bulk of millwork is produced from shop lumber, and the table following illustrates the thickness of such material, softwoods and hardwoods being included. This tabulation should enable the architect to determine, in most cases, the sizes of parts which he should specify in order to make the best use of available stock.

FACTORY AND SHOP LUMBER

Size board measure, inches	Softwoods		Hardwoods		
	S2S	Finished	Rough dry	S2S	Finished
1	$^{25}/_{32}$ and $^{26}/_{32}$	$^{3}/_{4}$	1	$1^{3}/_{16}$	$^{25}/_{32}$
$1^{1}/_{4}$	$1^{5}/_{32}$	$1^{1}/_{16}$	$1^{1}/_{4}$	$1^{1}/_{16}$	$1^{1}/_{32}$
$1^{1}/_{2}$	$1^{13}/_{32}$	$1^{3}/_{8}$	$1^{1}/_{2}$	$1^{5}/_{16}$	$1^{9}/_{32}$
2	$1^{13}/_{16}$	$1^{25}/_{32}$	2	$1^{3}/_{4}$	$1^{23}/_{32}$
$2^{1}/_{4}$	$2^{1}/_{8}$	$2^{3}/_{32}$			
$2^{1}/_{2}$	$2^{3}/_{8}$	$2^{11}/_{32}$			
3	$2^{6}/_{8}$	$2^{23}/_{32}$			
4	$3^{6}/_{8}$	$3^{23}/_{32}$			

This material is delivered by the sawmill in random widths, with the smallest limit of width 5 in., which must be full 5 in. in the rough-dry condition. Specified widths may be secured in shop lumber or in yard stock, just as standard industrial thicknesses, such as the $^{26}/_{32}$-in. finished thickness for 1-in. board-measure stock, may be secured in softwoods.

The grading rules covering softwood factory lumber are divided into two parts—factory clears and shop.

Factory clears include the upper grades of factory plank containing a high percentage of best-quality cuttings. This material is divided into two general classes:

No. 1 and 2 Clear Factory.—Lumber practically clear in wide sizes to contain not less than 85 per cent of No. 1 door cuttings, not including pieces with over two muntins, or muntins only.

No. 3 Clear Factory.—Lumber containing not less than 70 per cent of No. 1 door cuttings, not including pieces with over two muntins, or muntins only.

The other general division is "shop." This includes the lower grades of factory plank, yielding smaller percentages and smaller quantity of lower-quality cuttings. It is divided into:

No. 1 Shop.—Lumber of high-quality factory grade containing not less than 50 per cent of No. 1 door cuttings, allowing, if necessary, one No. 2 stile in any piece but no pieces with over two muntins, or muntins only.

No. 2 Shop.—Lumber containing not less than 25 per cent of No. 1 door cuttings, or 40 per cent of No. 2 door cuttings, or 33⅓ per cent of mixed door cuttings.

No. 3 Shop.—Lumber of a shop type below the grade of No. 2 shop and better than box lumber.

In the preceding table are shown the standard sizes board measure, finished thicknesses, and the maximum machine-finished thickness which can be produced from corresponding standard nominal thicknesses of lumber.

SPECIFICATIONS FOR MILLWORK

An examination of architects' plans covering a period of many years has resulted in the conclusion that little effort has been made on the part of the designer to use lumber economically. This condition has resulted largely from the fact that no definite standards have been set for the lumber industry previous to the last few years. No information, adequately covering this particular point, was disseminated. As a result, wasteful practices among specification writers and draftsmen came about. It was common practice to specify $^{15}/_{16}$-in. moldings, believing that $^{1}/_{16}$ in. would be ample for finishing on the molding and even for sanding, basing the specification on the assumption that 1-in. stock was full 1 in. thick.

On the contrary, to produce $^{15}/_{16}$-in. moldings it is necessary to go to 1¼-in. stock, greatly increasing the cost of the material entering into the manufacture of the finished product.

Those manufacturers who are producing large-quantity runs of stock materials studied lumber standardization very carefully. Some are still listing their materials under the "nominal thickness." As a result, architects drawing materials from these sources may not be getting what they anticipated, since they are using the nominal thickness as a final thickness.

Other manufacturers of woodwork who are producing standardized material in quantities are showing exact sizes in their literature, in order that architects may safely specify the finished size, with assurance that they will receive the material as it was specified.

The architect necessarily is interested in contour and design. He depends upon his moldings to produce the character he desires in the finished product. Those manufacturers who take the architect's specifications literally, and furnish the things he has designed (unless the architect has carefully studied lumber-standard sizes), very often lose out in

competition, although they are endeavoring to give the architect the item he wants.

A very good example of this is in the matter of casing and base. A 4-in. hardwood board will produce at best only a 3⅝-in. casing; and a 6-in. hardwood board, only a 5½ or 5⅜-in. base.

Another outstanding example is in the use and specification of 2½-in. sill stock, made necessary by the architect's detail, where all the inclination is put on the top face of the sill. A practice, which is just as good and much more economical, is to use 2-in. sill stock, so handled that part of the inclination of the sill is produced by raising the back edge of the sill, and all machining, so far as the thickness of material is concerned, is done on the top face. This method takes advantage of the entire thickness of the original piece, there being no waste except such as will produce the necessary contours.

The most intelligent and economical design is that which makes for the best interests of the client and the least wasteful use of material; and with intelligent and economical design go good principles of architectural design themselves.

The ingenuity of the architect should be such that he is able to create his designs successfully, within the limits of present American Lumber Standards.

Cooperation on this point from the architect, plus the interested effort of the millworker in pointing out the possibilities of American Lumber Standards, will further result in definite savings and improved design to the consumer, or ultimate buyer.

VENEERS AND PLYWOOD

Wood is a non-homogeneous material with widely different strength properties in the various directions relative to the grain. This difference must be recognized in all wood construction, and both the size and form of parts and the way woods are placed should be such as to utilize the different strengths along and across the grain to the best advantage.

It is not always possible to proportion a solid plank so as to develop the necessary strength in every direction and at the same time utilize the full strength of the wood in all directions of the grain. It is the purpose of plywood to meet this condition by cross-banding, which results in a redistribution of the strength of the wood.

In building up plywood an advantage is gained in obtaining equality of properties in two directions, parallel and perpendicular to the edge of the board. The greater the number of plys used in a given panel thickness the more homogeneous are the properties of the finished panel. To some extent, what is gained in one direction is lost in the other. A piece of plywood is not so strong in either dimension as a solid board of the same thickness would be in the direction of the grain, but for a large

number of plys it may be assumed that the tensile strength in two directions is the same and that it is equal to the average of the parallel-to-the grain and perpendicular-to-the-grain value of an ordinary board, while much greater than the strength of a solid board of the same thickness across the grain.

In its production, plywood is based on the process of veneering. There are three kinds of veneer—rotary, sliced, and sawed.

Exhaustive tests have shown that stresses in plywood, or laminated-wood construction, are often set up by using veneers produced by different methods. Where particular attention is to be given to strength and accurate shape of the resultant plywood or veneer product, it is very desirable that the same type of veneer be used in making the several plys of any product. In other words, it should be all sliced, or all rotary, or all sawed, because when the different types are mixed, unequal strains are set up in the plywood not only by the different types of material of which it is made but also by the moisture content of the glue which affects the different types of veneer unequally.

Although there has been a public prejudice against veneered products, in many ways plywood is preferable to solid wood, and in recent years, its use has extended itself in the woodworking industry very generally.

An example of long standing is in the furniture trade; more table tops, drawer fronts, doors, and side and end panels of all kinds of furniture are built up of three or five layers of wood than are made of solid pieces.

Besides permitting the use of cheaper material in cores and unseen surfaces, veneered construction has several advantages over the solid. These advantages should be borne in mind by the purchaser who thinks that veneering cheapens the product. The veneering process used in the development of built-up construction or plywood adds to the life of the product, eliminates the splitting, checking and warping, and, to a great extent, shrinking in broad surfaces.

Naturally, more care can be taken in the selection of surface wood in veneered construction than can be taken in the use of solid material.

With the advent of water-resisting glue, veneered doors, as an example, properly cared for, will last as long as or longer than the solid door. The glued joints, when correctly made, are stronger than the wood itself, under ordinary service conditions. Long exposure to damp air or direct contact with water will decrease the strength of the joint even when a water-resistant glue is used; but such service conditions would be almost as detrimental to solid doors, because even in the solid material the members are joined together with glue.

Rotary-cut Veneer.—The rotary-cut veneer is "peeled" off in a continuous layer from a rotating log. The wood is usually first steamed or boiled for several hours—in the case of oak, up to 40 hours—to soften it. The log, or rather, a relatively short part of the log, called a *bolt* or

veneer block, is put in a large lathe where a knife is automatically pressed against the wood so as to peel off a continuous sheet corresponding in width to the length of the bolt. This veneer sheet is cut up into suitable sizes. The thickness of rotary-cut veneer varies from $\frac{1}{120}$- to $\frac{7}{16}$-in.

The advantages of cutting veneer by the rotary method are that large pieces may be obtained and the work quickly done. The great majority of veneers are cut by this method, although only flat-grain surfaces may be obtained, which is a disadvantage in the case of those woods that are more beautiful when cut radially.

Sliced Veneer.—Sliced veneer is made by firmly clamping a flitch in a heavy machine. The wood is then moved up and down with a diagonal stroke before a heavy knife, which recedes slightly on the upward stroke and then moves forward a certain distance so as to take a slice off the flitch on the downward stroke. This method is used chiefly where radially cut veneer is desired and on such flitches as are cut for their beautiful figures.

A considerable quantity of quartered oak is cut in this way. The width of the sheets can be wider than the flitch, and very thin sheets may be secured; sheets as thin as $\frac{1}{120}$ in. and thinner have been cut by this method.

Sawed Veneer.—Sawed veneer is cut with a circular saw of special pattern. The saw is very thin at the edge, about $\frac{1}{20}$ in., gradually becoming thicker toward the center on one side, giving it the shape of a plain convex lens. The thin edge is necessary, in order to produce a thin saw cut, while the thicker center is necessary to give the saw strength and rigidity. The flat side of the saw faces the log or flitch to be cut. Although the other side springs the veneer as it is cut, it causes no trouble in cutting thin pieces. For this method, it is not necessary to soak or heat the wood before cutting it. It can be cut radially or in any other way. On the other hand, the veneer cannot be cut to the extreme thinness which can be obtained by slicing or rotary methods. An advantage of sawed veneer is that both sides are equally satisfactory for faces of panels, whereas in veneer cut with a knife, the side next the knife becomes cracked because the veneer is bent abruptly away from the bolt or flitch in cutting. A twentieth of an inch is about as thin as it is practical to saw veneer.

The sawed veneers are, perhaps, more perfect than either the rotary or the sliced, for the reason given above and, in addition, because they are not quite so porous.

In the rotary or sliced type in which the flitch or bolt is heated and steamed, the cutting edge of the veneer knife tends to expand the cells of the wood somewhat, causing some of them to fail entirely, which increases the porosity of the resultant sheets. This porosity, however, does not affect the production of millwork where veneers are used advisedly. The

porosity shows in the finished sheet. It is the cause, at times, of glue stain which is sometimes found in working with oak veneer. Careful selection can eliminate veneers showing too great porosity. Glue stain, as a rule, can be eliminated by careful handling; and while it shows up as a defect before the material is finished, it seldom is evident after oak work is stained and treated, because, as a general thing, the staining and treating turns the oak darker. The glue stain is no defect either structurally or artistically, for these reasons.

Details which visualize the veneering process are presented in the following parts of this chapter, in connection with various commodities discussed under Millwork, particularly in connection with paneled doors and doors having veneered stiles and rails. Examples of both thin and thick veneers are there shown.

EXTERIOR MILLWORK

Exterior millwork includes frames for entrance doors and windows, lattices, doors for exterior purposes, side lights, windows or sash, dormer-window frames, columns, newels, balusters and rails for porch work, rafter ends, brackets, gable terminations, flower boxes, seats, and all exterior moldings which produce cornices; also, gutters of solid sections, or the molded material from which gutters are built up. Material surfaced four sides but not molded is generally excluded. In some sections of the country, some of this S4S material is included in the mill list, but generally speaking, it is not. In comparing competitive bids, architects, should look carefully into this point, since local practices are not always followed by all those who may be invited to bid, particularly because in recent years there has been a marked increase in the movement of builders from one section of the country to the other. A complete set of mill figures often varies greatly, by reason of these items' being included or eliminated on the basis of the habits of the individual builder.

The pines, Douglas fir, redwood, western red cedar, and cypress are the woods commercially used, in quantities, for exterior millwork items. Relatively, the pines represent a majority of the material commercially distributed; and while all of these woods depend for their length of life upon careful painting, they are, generally speaking, of equal value from the standpoint of durability and service.

Attention is again called to the commercial sizes available, as evidenced in tables appearing elsewhere in this chapter, drawn from American Lumber Standards. While exterior moldings and other forms of exterior woodwork available from stock producers vary greatly as to their architectural character, it is possible to find under quantity production and standardized practices, good moldings which take into account in their manufacture the economical sizes of rough lumber as produced by the sawmills. For unusually large houses, where elevations require

heavier treatment, it is suggested that the architect investigate carefully the available sizes of material, so that the ultimate buyer may be given the advantage of every possible economy.

Window Frames.—From the standpoint of economical maintenance, numbers sold, and effect on the cost of heating, window frames are among the most important of the articles of exterior woodwork.

Typical details of window frames for various types of construction are to be found on accompanying pages. There are several points of construction shown in these typical details which are worthy of serious consideration. The particular frame illustrated is generally available through retail lumbermen and is an outstanding example of the results of careful study of the possibilities of standardization, quantity production,

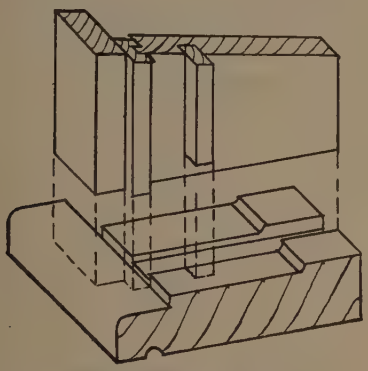


FIG. 84.—Connection at sill and jamb—approved construction.

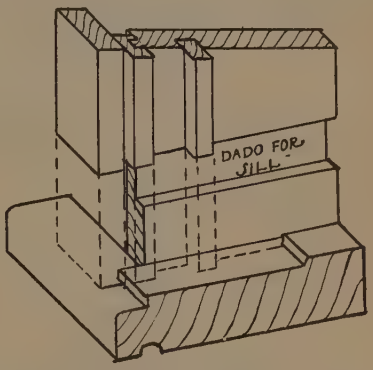


FIG. 85.—Connection at sill and jamb—common construction.

and the incorporation in a standard item of those features which make for maximum value to the ultimate buyer.

The purpose of a frame is to provide a means of operation for the windows and to seal effectively the "joint" in the wall between the wall proper and the window itself against moisture, water, and air.

Frames of many different designs have been produced and are now offered, each intended to minimize air and water leakage. Figure 84 illustrates the method of joining the sill and jamb in a frame of good construction. Figure 85 illustrates the method at the corresponding point in frames commonly used.

Rain striking the jamb runs down the jamb to its meeting point with the sill. In Fig. 84, there is no opportunity for the water to go through the sill. It will simply run to the outside edge of the sill, because of the slope, and then drain to the ground. In ordinary frames, the parting stop groove in the jamb extends through to the bottom of the sill, as shown in Fig. 85. Water entering the parting stop groove at any point above the sill, or at the intersection of the sill and jamb, can follow around

the dado, backing up against the plaster below the bottom of the sill. This form of construction is often responsible for water leakage around windows and for the destruction of expensive wall coverings.

Storm windows depend for their effectiveness upon the tightness of their fit. Figure 86 illustrates the $\frac{5}{16}$-in. shoulder in the sill of a good

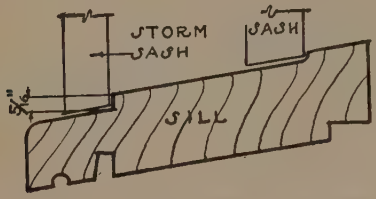


FIG. 86.—$\frac{5}{16}$-in. shoulder in approved window frame.

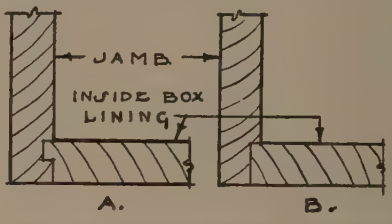


FIG. 87.—Jamb and inside box lining—*A*. approved construction. *B*. common construction.

frame, $\frac{3}{16}$ in. greater than in the ordinary frame. This heavy shoulder forms a more effective "stop" at the bottom of the window, a tighter joint against water and air. With wear, or improper fitting of the sash, the $\frac{1}{8}$-in. shoulder often used on ordinary frames may become entirely ineffectual.

Full advantage of the entire thickness of the jamb is available, to make easy the carpenter's job of applying trim. On the average frame, the inside box lining is let into the jamb by its full thickness, materially reducing the available nailing area.

In Fig. 87, the inside box lining of the frame is tongued through only half its thickness as shown at *A*. This construction forms a much better weather-break and gives a wider and more solid nailing surface against

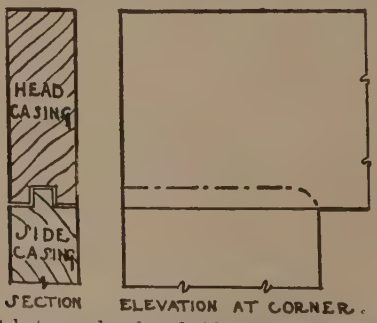


FIG. 88.—Joint between head and side casings—good construction.

which to apply trim. Compare nailing surfaces in frame *A* and in the ordinary frame *B*.

The two sketches in Fig. 88 indicate the method of union between head and side casings of a good frame. The average frame has the common butt joint at this point. The tenon of this mortised-and-tenoned joint

holds the faces of the side and head casings in line, provides a tight joint, and eliminates any chance of air or water leakage at this point. It gives to the frame all of the value of a wide blind stop and the further advantage of a better finished frame from the standpoint of exterior appearance.

The following features are of particular interest to the architect or builder who desires to build into a home the maximum of comfort, at reasonable initial and maintenance cost. Reference should be made to complete frame details, which follow, as well as to the figures directly mentioned.

1. Head casing cap. When not used in the molded cap form, the cap is rabbeted. In all frames the cap should have a water drip plowed throughout its length to prevent water leakage, as shown in Fig. 89 (*cf.* figures *a*, *b*, and *c*). The plain drip cap, as illustrated in Fig. *b*, and the drip cap with plain rabbet will permit water to run back behind the head casings or down to the joint of the head and side casings.

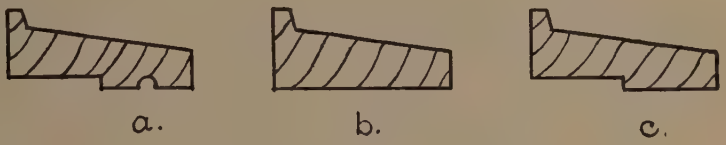


FIG. 89.—Head casing caps.

2. The head casing is mortised to receive tenon on side casing, forming water- and airtight joint. This construction adds to the exterior appearance, since the joint cannot open up, as illustrated in Fig. 88. A plain butt joint is commonly used.

3. The jamb has a heavy tongue run into blind stop, preventing air and water leakage at this point. This is shown by the jamb section, *Plate* 33.

4. The sill and the head jamb are dadoed to receive the side jambs, as shown in Figs. 84 and 85. This is one of the most important and advantageous features of this frame detail.

5. The lip or rabbet on the sill forms a tight joint against the bottom rail of the lower sash, when the sash is closed. The extra-heavy rabbet, as shown in Fig. 86, forms a stop for screens and storm sash, insuring a watertight storm-sash job. These features combine to make a sill of maximum effectiveness, eliminating drafts and reducing coal bills.

6. The inside edge of the side jamb is not cut away by a rabbet of doubtful value. In ordinary frames, this rabbet extends all the way through to the inside edge of the jamb, for the supposed purpose of receiving the ground strip. It is seldom so used. In the frame illustrated, the entire thickness of the jamb is available for the application of the trim. This is illustrated by Fig. 87. This point is greatly appreciated by the mechanic.

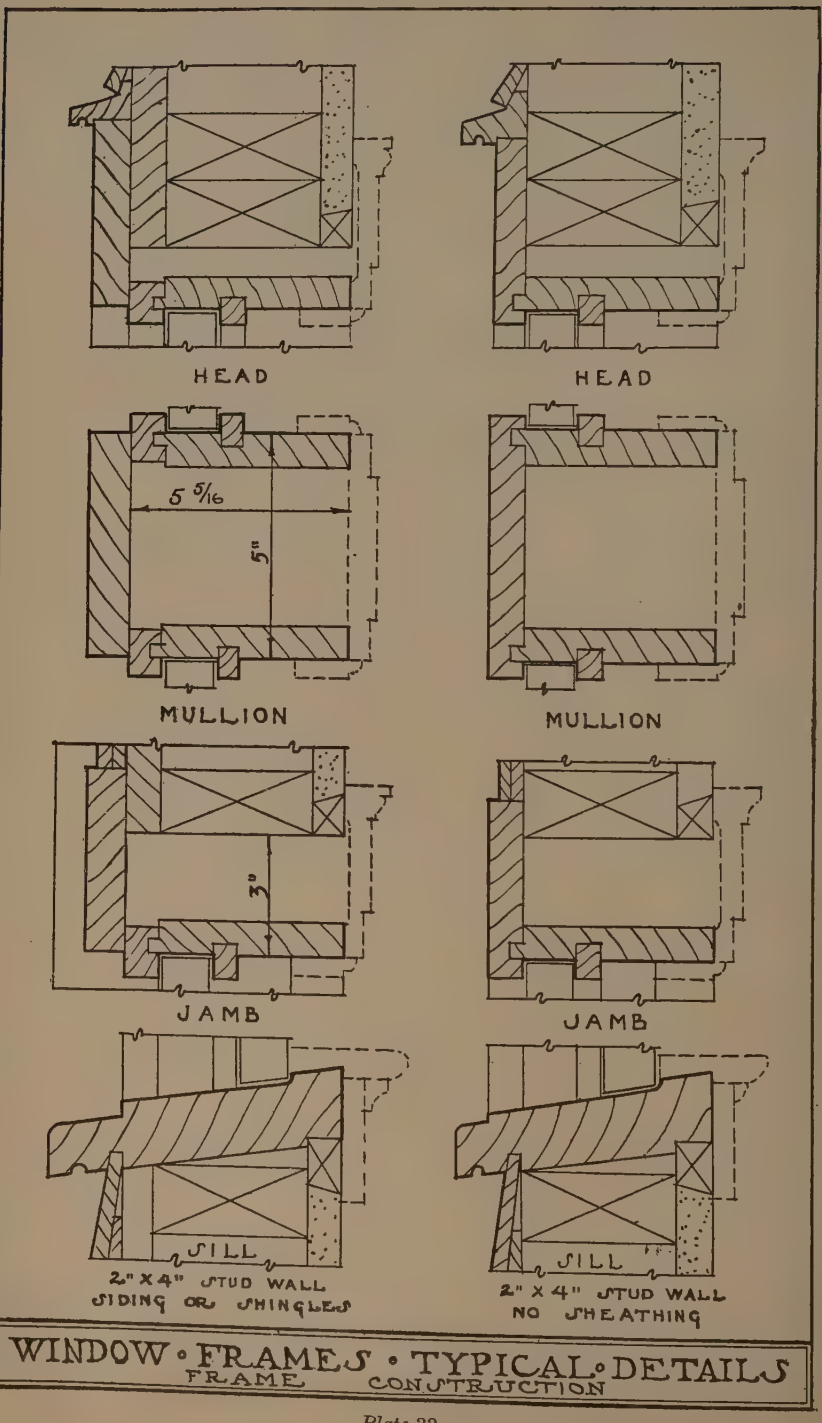
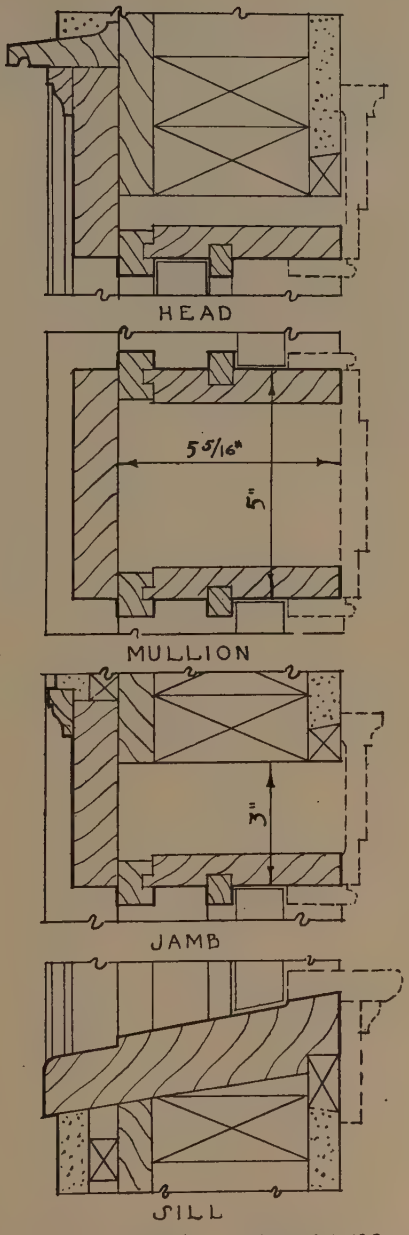
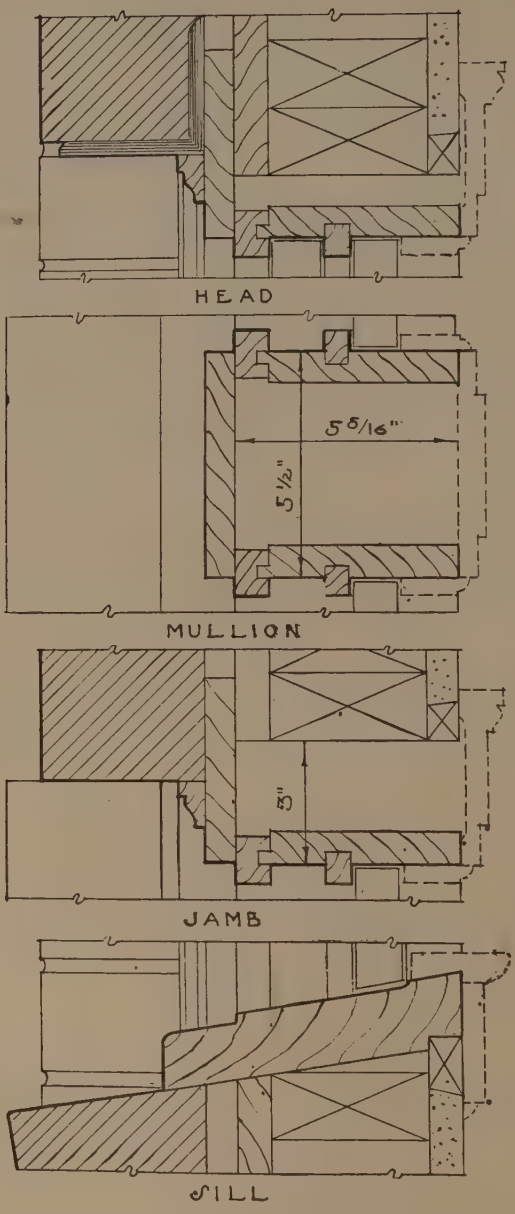

HEAD
HEAD
5 5/16
5"
MULLION
MULLION
3"
JAMB
JAMB
SILL
2" X 4" STUD WALL
SIDING OR SHINGLES
SILL
2" X 4" STUD WALL
NO SHEATHING
WINDOW • FRAMES • TYPICAL • DETAILS
FRAME CONSTRUCTION

Plate 33.



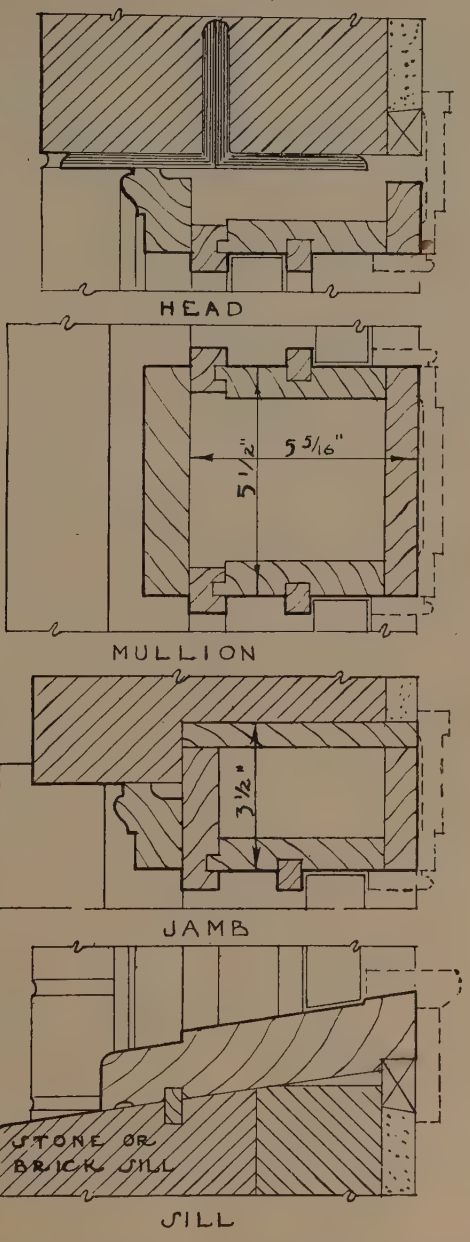
WINDOW • FRAMES • TYPICAL • DETAILS
FRAME CONSTRUCTION

Plate 34.



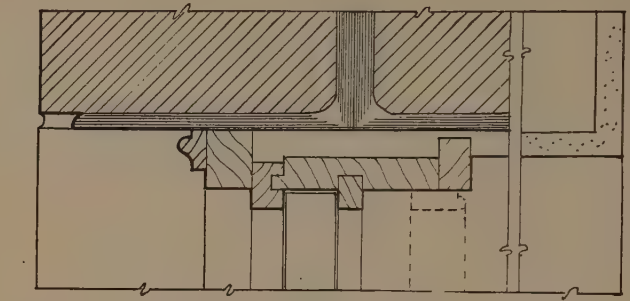
WINDOW • FRAMES • TYPICAL • DETAILS
BRICK VENEER CONSTRUCTION

Plate 35.



WINDOW · FRAMES · TYPICAL · DETAILS
8 INCH BRICK WALL

Plate 36.



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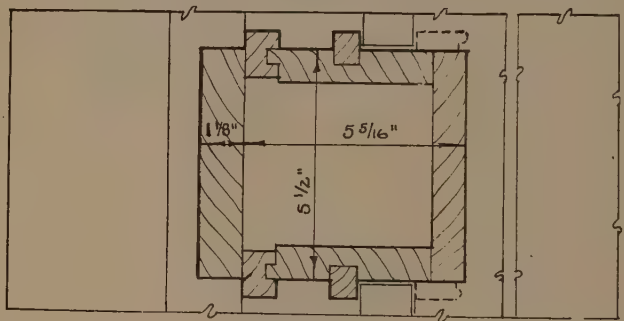
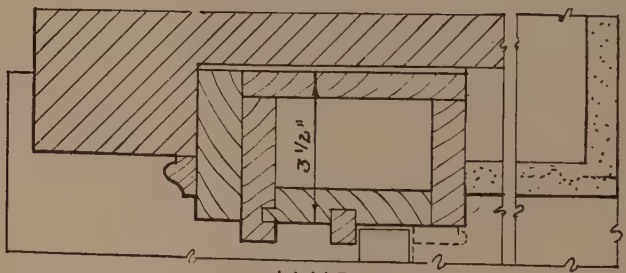
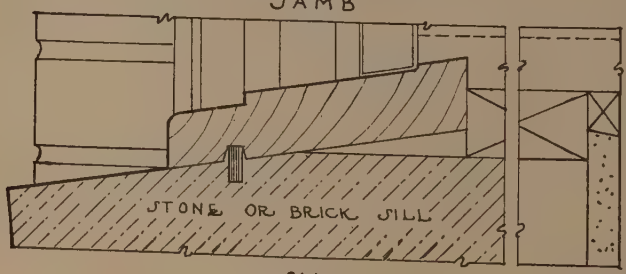


MULLION



JAMB



SILL

WINDOW · FRAMES · TYPICAL · DETAILS
STONE OR BRICK CONSTRUCTION

Plate 37.

7. The sill is rabbeted to receive inside ground, a further stop against air infiltration. This rabbet can also be used as a shoulder for nailing the lath, wall board, etc., as shown in the sill section, *Plate* 33.

The sill is rounded on a $\frac{5}{32}$-in. radius to prevent slivering of the wood and to present a better surface for painting, as seen in Fig. 86.

The underside of sill is plowed at the line of sheathing to receive siding or shingles, showing a second means of preventing air leakage beneath the sill. It is likewise plowed near the front edge to form a water drip, as shown in Fig. 86.

8. On mullion frames, the mullion jambs, dadoed into full-length sills and head jambs, make a much more rigid frame. It is common practice to cut the head jamb into the mullion jamb.

9. The machining on every part of a frame should be of the highest order throughout. *Plates* 34, 35, 36, and 37 show window-frame details for stucco, brick veneer, and solid masonry construction.

Figure 90 shows method of joining the jamb and blind stop as used by some millwork manufacturers.

These features give added value, greater durability, and greater elimination of air and water leakage. All this means greater value to the home owner, since each feature points to a definite saving in the cost of maintenance and upkeep.

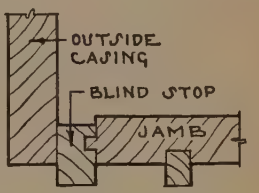


FIG. 90.—Jamb and blind-stop connection.

Windows and Sash.—In the last few years, much has been accomplished by the woodworking industry in reducing the number of sizes of items made in stock quantities. An indication of progress along this line is seen in the experience of one woodwork concern, which reduced the total number of sizes of two-light windows from 193 to 93, with a resultant loss of total volume of but 7 per cent immediately following.

In other words, 7 per cent of their sales of double-hung, two-light windows represented 100 sizes; whereas 93 per cent of their sales volume represented the 93 sizes which were retained.

One of the reasons for the multiplicity of these sizes is found in the different manufacturing processes followed by different mills and in varying practices of local origin. Some cities in the United States have, for many years, followed a certain "wood allowance" for windows or sash. This was due to a local manufacturing process, in a city where the majority of the requirements of the community were taken care of by a local concern.

Since the tendency within the last 15 years has been more and more toward standardization, it has been somewhat easier for the industry as a whole, practically to standardize on two different sizes of "wood allowances" in windows and sash. These are generally understood as the

eastern and western openings (see *Plate* 38), the difference lying in the amount of wood which surrounds the glass, plus the amount of wood represented by the division bars and muntins or rails in a given section.

The size of a window is made up of the total size of the glass, plus a certain number of inches in width and a certain number of inches in height, those inches measuring the horizontal or perpendicular width of wood which surrounds or divides the glass. As an example, the usual 12-light window, has 4½ in. of wood in a section cut horizontally through that window. This is made up of two muntins ¼ in. wide each and two stiles 2 in. wide each. Vertically, this wood allowance is made up of two bars ¼ in. wide, a top rail 1¾ in. wide, a check rail 1 in. wide, and a bottom rail 2¾ in. wide. These dimensions are for the western opening.

In the same window, for the eastern opening, the vertical wood allowance is the same, but the horizontal wood allowance is 4 in. and is made up of two muntins ¼ in. wide each and two stiles 1¾ in. wide each.

It is the desire of the leading producers in the industry to standardize upon one general plan of wood allowance, and thus make possible a reduction in stocks which necessarily must be carried, not only of finished windows but also of window parts and the frames which they must fit. A definite saving could be made throughout the building industry as a result of a movement of this kind, and the public would receive the benefit.

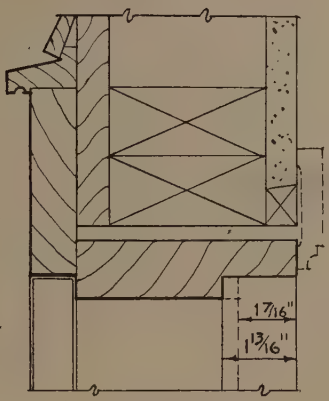
The purpose of a window is to admit light, to make ventilation possible and at the same time to act as a barrier to heat and cold alike. It is obvious that, as long as structural strength is sufficient, a window the wood parts of which total 4 in. in width is just as practical as one in which these same parts measure 4½ in.

The home owner benefits more than anyone else from uniform practices, and these practices can best be furthered by making to one detail and size parts which are suitable for a single purpose.

It is the apparent duty of all connected with the woodwork industry in any capacity to further this idea of economy; and whenever anyone can favorably influence any factory within the industry to a standard wood allowance, the result will be reflected in lower building costs.

Where the top and bottom sash of a double-hung window meet, the bottom rail of the top sash and the top rail of the bottom sash form a *check rail*. Three kinds of check rails are commonly produced. They are the rabbeted check rail, the ordinary beveled check rail, and the plain rail indicated in *Plate* 38.

The window generally considered to be the most satisfactory has a beveled and rabbeted check rail. In addition to the rabbet in the check rail, which materially retards air infiltration, there is indicated a putty groove which, when the sash is glazed, acts as an additional key for the putty, adds to the holding surface of the wood area upon which the putty is placed, and increases the value of the finished product.



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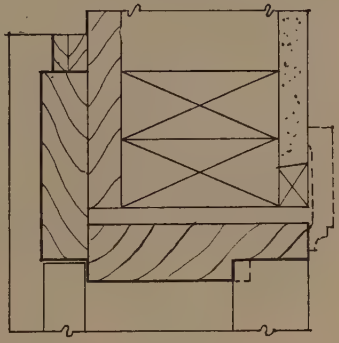
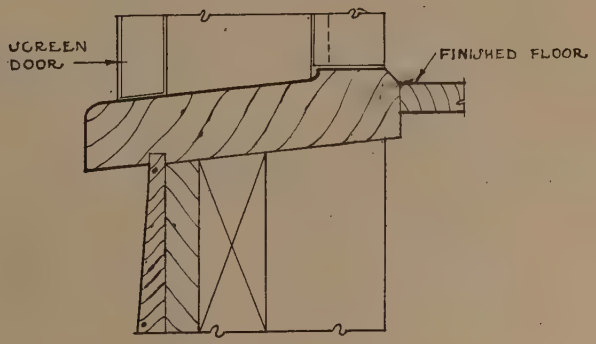


JAMB

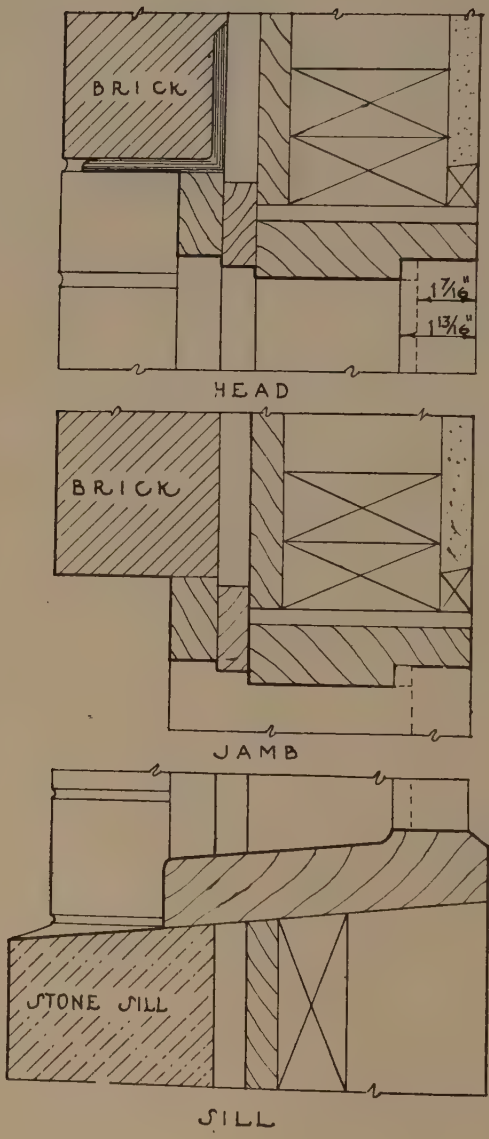


SILL

2"X4" STUD WALL

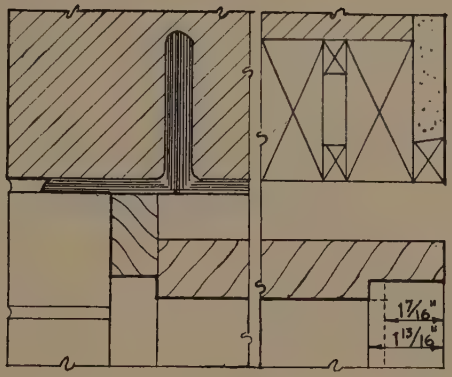
DOOR · FRAMES TYPICAL · DETAILS.
FRAME CONSTRUCTION

Plate 46.



DOOR • FRAMES • TYPICAL • DETAILS
BRICK VENEER CONSTRUCTION

Plate 47.



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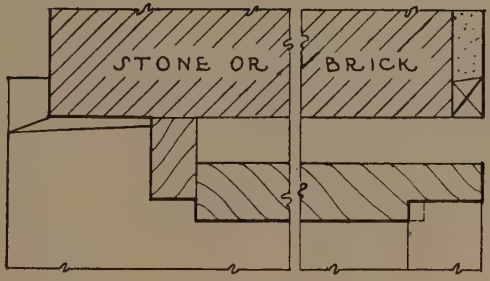


JAMB.

SILL.

DOOR · FRAMES · TYPICAL · DETAILS
MASONRY CONSTRUCTION

Plate 48.

from the standpoint of the ultimate buyer, than would be possible through the maintenance of stocks of jambs rabbeted only for 1⅜-in. doors.

In masonry construction, the wood sill is eliminated, the jambs of the frame finishing on the top of the stone sill. In all other forms of construction, the jambs extend to the bottom of the wood sill, being nailed into the sill ends.

In Fig. 92 are shown several common types of interior door jambs.

Extrance Frames.—The entrance is usually somewhat highly detailed as compared with almost any other portion of the millwork which forms the exterior decorative material; this is particularly true in the construction of a home. The detailed entrances which are shown on *Plate* 49 are included simply to indicate the possibilities of the adaptation of ready-made items of this highly developed character, which will be found to indicate good architectural lines.

They differ in their construction details from the average exterior door frame in that they carry considerable detailed embellishment, for which provision must be made.

A general recommendation covering these entrances is that they be made of wood with fine painting qualities and maximum resistance to decay and that they contain oak sills. The specification insisting on an oak sill is desirable, if a wood sill is used. The practical entrance frame is one which must be adaptable, of course, to the use of a stone sill, and this fact is taken into consideration by many manufacturers, certain parts of the frame simply being removed to provide for this change.

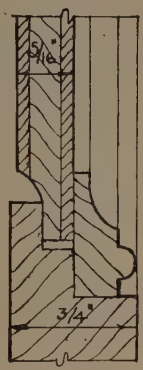
Because of certain structural requirements imposed by the design of entrance frames, the details applying to stock door frames, discussed previously, do not always apply. The use of these stock parts where possible, however, is economical.

Other Exterior Millwork Forms.—Cornice material, exterior moldings, porch columns, balusters, and rail constitute the remainder of exterior woodwork forms.

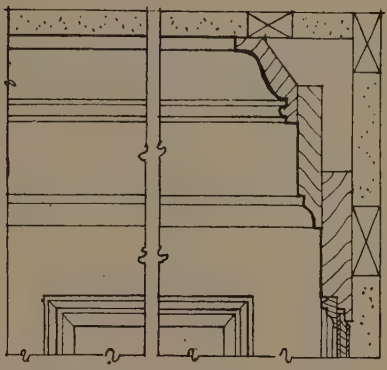
Cornices are of either the boxed or the open type. In both types they depend for their architectural effect largely upon the moldings of which they are composed. Cornices are built by the carpenter on the job, to the detail of the architect. Since they are in exposed positions, careful workmanship in erection and painting is of utmost importance.

Exterior moldings, porch balusters and rail, and smaller posts are of solid sections. Good machining and good-quality material are required for first-class work. A wide variety of forms and designs are offered under quantity production, from which the designer can choose his requirements.

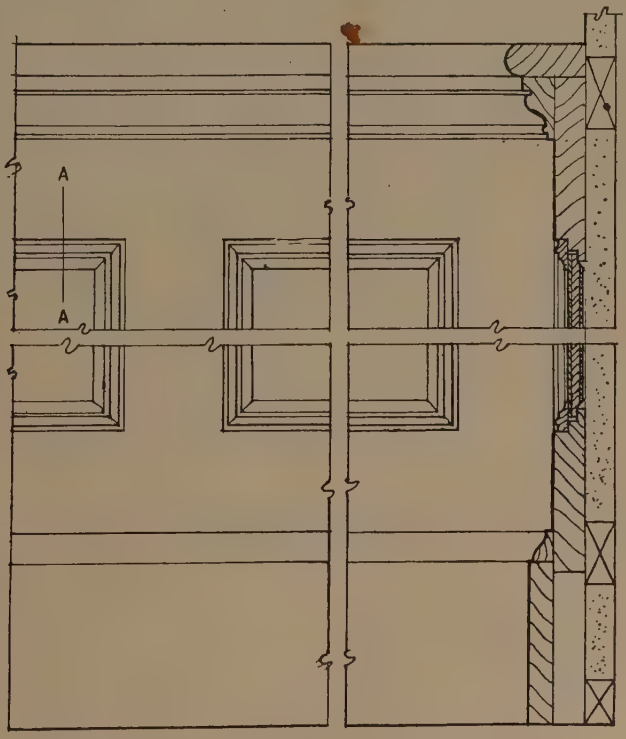
Porch columns present construction problems, in that their size often makes it impossible to produce them of solid materials. The quality of joining and gluing determines the serviceability of the resultant product. Some of the methods in common use are detailed in Figs. 93 and 94.



SECTION
THRU A-A



DETAIL OF PANELING
CARRIED TO CEILING



DETAIL OF WAINSCOT

PANEL WORK ... TYPICAL DETAIL
WALL PANELING

Plate 50.

in the size of the panels for the variation in the room size and those restrictions put upon the panelwork by the location of door and window openings.

Progress has been made by certain manufacturers toward a semi-standard production of interior panelwork in which the horizontal divisions between panels vary only as to length, and where the vertical divisions between panels which vary similarly are stub-tenoned into the horizontal divisions or the rails.

Strength is gained by this method, which also insures against warping or twisting to a marked degree. A strong frame can thus be made from relatively thin lumber in standard thickness.

Plate 50, particularly at sections *A*–*A*, shows that standard 1-in. finish lumber has been machined and sanded to a ¾-in. thickness, a 5/16-in. three-ply panel has been inserted in the rails and stiles, and they have been properly grooved to receive it. After that, the panel mold is mitred around, forming an interesting detail. Note that the 5/16-in. panel has been beveled at the back, in order that the ¾-in. frame material may be used. This type of panel-frame construction adapts itself to the use of any given base or cornice mold, and the standard parts may be used by taking them into consideration when the original layout of panelwork is made. By proper selection of panel molds, different design treatment may be secured.

The form of construction shown on this typical detail has proved eminently satisfactory and can be adapted to special work at only a slight increase in the cost of using the manufacturers' standard parts throughout.

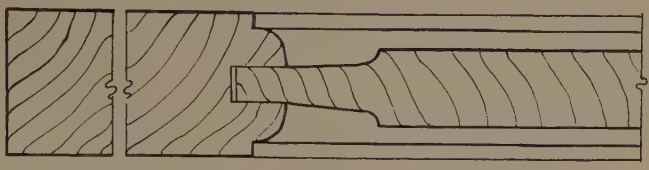
This particular detail, produced in oak for English work and in soft pine for colonial work, has the authorship of one of America's leading architects and is adaptable to either style, depending upon the wood used, because it follows a generally accepted Georgian motif.

Doors.—All doors are classed, from a construction standpoint, as (*a*) panel doors and (*b*) slab or flush doors. Glazed doors follow the same general detail of panel doors.

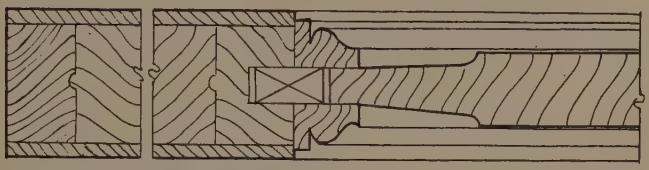
The panel door is one which is made up of stiles, rails, and one or more panels, the rails and stiles forming the frame around the panel. These rails and stiles are of either solid or veneered construction. They are the members which produce the strength and architectural characteristics of the door itself. Figure 96 shows common types of stock doors, and Fig. 97 two methods of joining the stiles and rails.

The slab door is one which is built up on the basis of veneered construction and is usually made of five plys—that is, two plys of cross-banded veneer on either side of a central core.

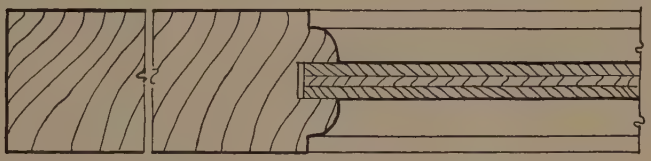
Panel Doors.—Panel doors are divided into solid and veneered types. Here the term *veneered* refers to the stiles and rails. In *Plate* 51, Fig. *a*



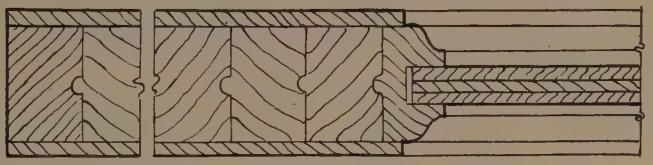
a. SOLID MOLDED DOOR STILE & PANEL.



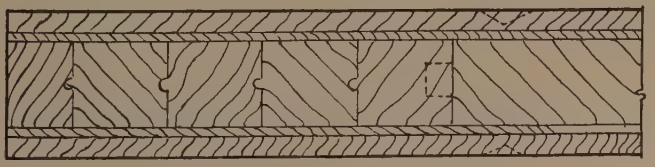
b FLUSH MOLDED DOOR STILE - VENEER CONSTRUCTION.



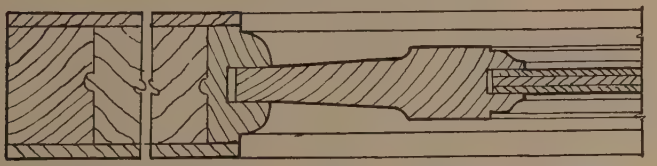
c. SOLID MOLDED DOOR STILE - VENEERED PANEL.



d. VENEERED STILE AND PANEL.



e FLUSH VENEER DOOR.



f VENEERED PANEL SET IN INSERT FRAME.

STOCK DOORS TYPICAL DETAILS.

is shown a solid stile or rail; and in *b*, a veneered stile or rail. Illustrations *c* and *d*, show the solid and veneered stiles and rails, respectively, but a different kind of panel.

In Figs. *a* and *b* is shown a solid raised panel; in Figs. *c* and *d*, a laminated, flat panel.

In Figs. *a* and *c*, the molding which frames the panel is cut into the stile and the rail and is a part of both of those members.

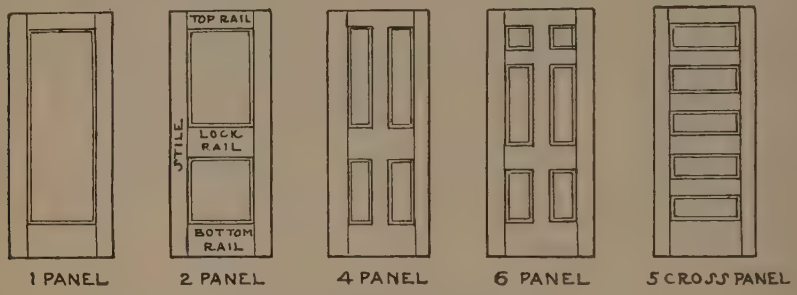


FIG. 96.—Typical stock doors.

In detail Fig. *b*, the molding is applied, from which fact is derived the term *flush-molded* door. There are a great many different contours of moldings, either in stuck moldings or applied moldings, and since the architect is interested in this largely from a design standpoint, it will not be covered in this discussion, which has primarily to do with construction details.

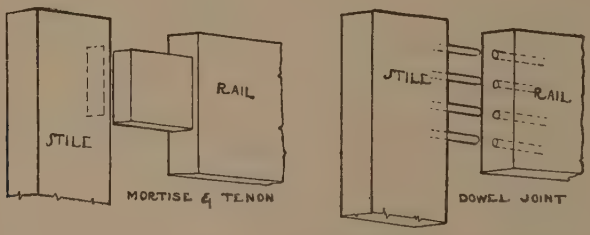


FIG. 97.—Two methods of joining the stile and rail of a door.

Door constructions of the types in Figs. *a*, *b*, *c*, and *d* have been in use a relatively long time. In more recent developments having to do with improvement of durability in service, much progress has been made possible by a better understanding of the handling of the moisture content in the wood and by developments in water-resistant glue and gluing practices.

A relatively recent development within the industry is door constructions of the type illustrated in Fig. *f*, which shows panel doors with the panel set in an insert frame, the frame being again set into the stiles and rails. Similar doors are made with solid rails and stiles, instead of the

veneered section. The five-ply flush door shown in Fig. *e* is constructed of softwood core blocks, with cross-banded veneers on either side.

On each edge of a door of this type, a stile is built up of core blocks, with an edge strip of the same wood as the face veneer. There are also edge strips at the bottom and top of the door. The space between the stiles is filled in with horizontal cross-rails of equal width, tongued and grooved together. These rails are themselves built up of softwood core blocks, tongued and grooved together. Each cross-rail is tenoned into the stiles and, in addition, is doweled into the stiles at each end.

On either side of the core so built up, two layers of veneer are applied, the cross-banding usually of $\frac{1}{16}$-in. veneer, and the face of $\frac{1}{8}$-in. veneer. This represents the usual type of five-ply slab-door construction. Figure *e* indicates the use of $\frac{1}{4}$-in. veneer on the outside faces, to provide sufficient depth to allow grooves to be cut, by the use of which the plank door is simulated; $\frac{1}{4}$-in. veneer allows a deep groove, producing the desired effect and still leaving sufficient thickness of veneer to insure proper durability and service.

The above six details cover generally the construction of doors in so far as approved methods are concerned.

Material for Cores.—The prime requisite in material for cores is that it shall be subject to a minimum of shrinking, swelling, or warping. Core lumber is waste from sash and door cuttings and, as used by the best operators, is entirely clear lumber. These small blocks are tongued, grooved, and planed to proper thickness after they are cut to the desired width, which allows the machine operator to reverse the grain in each block as it passes through the planers and stickers. Water-resistant glue is automatically spread upon these blocks as they come through to the operator, who arranges them between edging strips of the same wood as the veneer to be later applied. This built-up stile and rail resists warping and twisting to a maximum, because the grain is reversed in the various core blocks and such tension as may be set up in one of them is counteracted, on the average, by the adjacent one.

In the process of gluing, a certain amount of moisture is taken in by these core blocks. In the best practice, these rough stiles and rails are stored in a "hot box," until they have been brought back to the average moisture content which prevails throughout manufacture.

The rough stiles are then planed to the proper thickness, spread with glue on either side, veneered, and held under pressure until the glue is permanently set.

The veneer used on the majority of good doors is classed as $\frac{1}{8}$-in. veneer, which, after sanding, is brought down to $\frac{3}{32}$ in. in the finished door. This is of some advantage in woods which are susceptible to "glue stains," since the diffusion of glue through the veneer becomes gradually less noticeable as the veneer thickness increases above

1/20 in. All hardwood doors in commercial production today are veneered. This process not only reduces the cost but also increases greatly the durability and value of the product. Recently, for similar reasons, the production of softwood doors of the veneered type has been increased materially.

Since the World War, considerable progress has been made in the improvement of so-called *waterproof glue*, studies for which were actuated by necessity at the time of America's entrance into the war. For commercial usage, however, no glue is entirely waterproof. Continued exposure to moisture will weaken glue joints made according to the most approved commercial and private glue formulæ. The weakening of these joints, however, is only relative and is not of major importance. The care which the door receives after it is delivered to the building and installed therein is important.

The ends of the stiles, as well as the top and bottom rails, should be very carefully protected, just as soon as the material is delivered to the job. The grain at the end of the stiles is the most important thing to consider, because moisture follows this end grain through into the piece much more quickly than it does when it has to penetrate against the grain, as in the case of the top and bottom rails. The application of white lead and oil is a very practical means of eliminating the penetration of moisture at this point.

Care of Doors.—Doors are frequently damaged by improper storing in the warehouses of distributors and dealers. The most common method of storing them in stock is to pile one upon another. The door at the bottom of the pile is placed on the floor and one door after another is laid on until a pile approximately 6 or 8 ft. high is made.

It can readily be realized that if the floor is uneven, as a majority of warehouse floors are, the doors under the pressure of the completed pile will naturally conform to the contour of the uneven floor. Doors in stock are often left in piles 6 months, or longer, and if the floor on which they are piled is uneven, they will take on a permanent misshape.

To avoid this, the doors should be piled on two cross-members, approximately 2 by 4 in. and of a length to extend slightly beyond the edges of the doors. These 2 by 4-in. pieces should be placed about one-fourth the total length of the door from each end to balance the weight and prevent sagging in the middle. There should be only two supporting cross-members, as more would cause twisting of the doors.

Interior Trim.—The woods most generally used for interior trim are soft pine, southern pine, Douglas fir, oak, birch, and gum. All of these woods vary somewhat in their adaptability to paint and natural finish and are selected by reason of their special suitability for a particular use.

A few general rules which should govern the selection of the material itself are as follows:

1. It should be free from resin, sap stain, and pitch pockets.
2. It should resist warping and be of good working qualities.
3. Standard interior trim should have no defects, unless in long lengths where the defects may be eliminated by cutting, as it is applied to the job.
4. All interior trim should be run from carefully kiln-dried stock, to insure against open joints, warping, and twisting.
5. All wide-trim members, such as base and casing, should be backed out, which is an advantage in fitting and, in addition, is somewhat of a guarantee against warping.
6. All flat surfaces of trim should be fully sanded. This operation can be done most economically at the mill, eliminating the necessity of sanding on the job. Raised grain on the face of sanded trim is a common fault, but it is not a defect. It is the result of incorrect kiln drying or incorrect handling after manufacture and usually arises from the character of the storage space where it is held ready for sale and delivery. Slightly raised grain in trim adds somewhat to its cost of installation but aside from this drawback should not be considered as an important defect in connection with stained or natural finish. Raised grain is an important defect where a high grade of enamel finish is to be used.

Sap stain (rule 1) should not be permitted in any first-class work. Stained sap is the result of a fungus growth, and if the wood is not thoroughly dry and carefully handled, the fungus will continue to develop even after the wood is painted. It is possible to kill the fungus by high degrees of heat, and if it is actually killed, sap-stained lumber becomes a thoroughly satisfactory material for paint work. Since woodwork goes to the job "in the white," however, and the appearance of stained sap in any of the items is usually unsatisfactory to the consumer and a reflection on the manufacturer, sap stain is listed as a blemish that should not be permitted in first-class woodwork.

Leading trim manufacturers make it a practice to run all of their trim from kiln-dried lumber to steel templates, insuring through this method a constant cross-section and contour. This process insures the actual matching of cross-section and contour in different runs.

One very important item in the running of trim is the regulation of the speed of the knives to the particular wood which is being run. In the selection of a source of supply for trim, therefore, it is always well to know the amount of study and thought given this particular phase of the production of millwork. The matter of speed of cutter heads and the technique of kiln drying follow no definite and prescribed rules, the knowledge of the operators being the controlling factor in the value of the resultant product.

Recent developments within the industry have brought forth the practice of bundling trim in cartons—a precaution designed to keep the

moldings clean, dry, and free from marring, also to make them less susceptible to the absorption of moisture. The vast majority of trim, however, is still sold in long lengths, probably because the ultimate buyer does not appreciate the actual saving and improved value of the material when it is carton packed.

In line with the recommendations of the American Lumber Standards Committee, trim and moldings of good architectural design are becoming available nationally. Recent developments have resulted in a number of combinations of exceedingly narrow trim, which further reduce the cost of trimming openings. This narrow trim is made up of smaller moldings, which are available in so many different contours that the architect can make up almost any size of any trim he desires, from these standard pieces. A method of application of narrow trim is detailed in *Plate* 52, since, to accommodate the narrow type of trim to the usual double-hung window frame, a slightly different construction must be used.

In *Plate* 52 typical examples of interior trim also are shown.

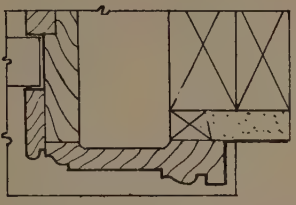
Stair Material.—The development of standard practices by a number of individual manufacturers for the design of volutes, goosenecks, and other curved members used in connection with stairways frequently makes their use possible. These standard practices have been brought about by a long study of the requirements for stair parts and their use often results in economies to the purchaser.

These practices provide for quantity instead of one-at-a-time production on items, the unit price of which has always been extremely high; thus eliminating handwork and substituting for it machine work of much better average character. In this way, exact and correct detail is produced, and variation is eliminated.

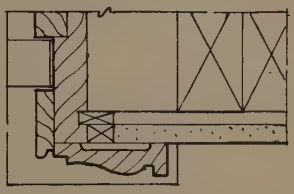
The architect's ingenuity enables him to develop from these stock parts the individual effect he desires to secure in his stair. This can be done with possibly no more study, and frequently in less time and with less effort, than would be required for complete detailing, and with a resultant saving in cost to the client.

The details appearing herewith indicate the possibilities of the adaptation of certain stock parts to given situations and clearly illustrate them.

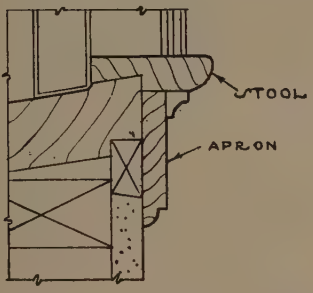
In a stair of the type shown in *Plate* 53, established high-grade practice demands that the scroll end of the starting tread follow the contour of the volute. The scroll end is made by veneering over a properly shaped softwood kiln-dried core. This method produces a continuously smooth surface, which will be durable over an exceedingly long period of time. The starting newel is anchored by a very long dowel turned on its lower end into the softwood core. The balusters carry a similar dowel pin which goes down through the riser. Since the upper end of the balusters is let into the volute, an extremely strong balustrade is provided.



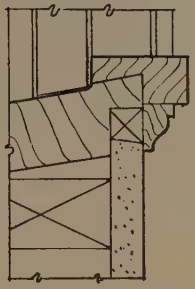
TYPICAL WINDOW TRIM



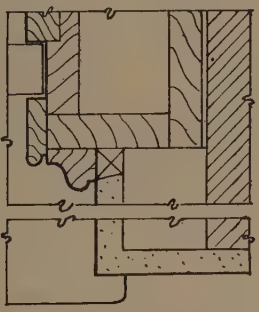
NARROW WINDOW TRIM

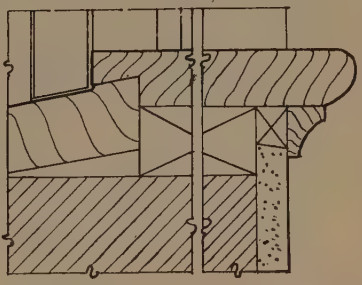


TYPICAL WINDOW STOOL

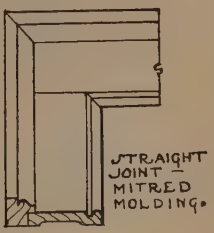


STOOL WITHOUT APRON





WINDOW TRIM & STOOL IN MASONRY OPENING - PLASTER JAMB.



METHODS OF JOINING HEADS & SIDES OF WINDOW & DOOR TRIM.

INTERIOR · TRIM · TYPICAL · DETAILS

Plate 52.

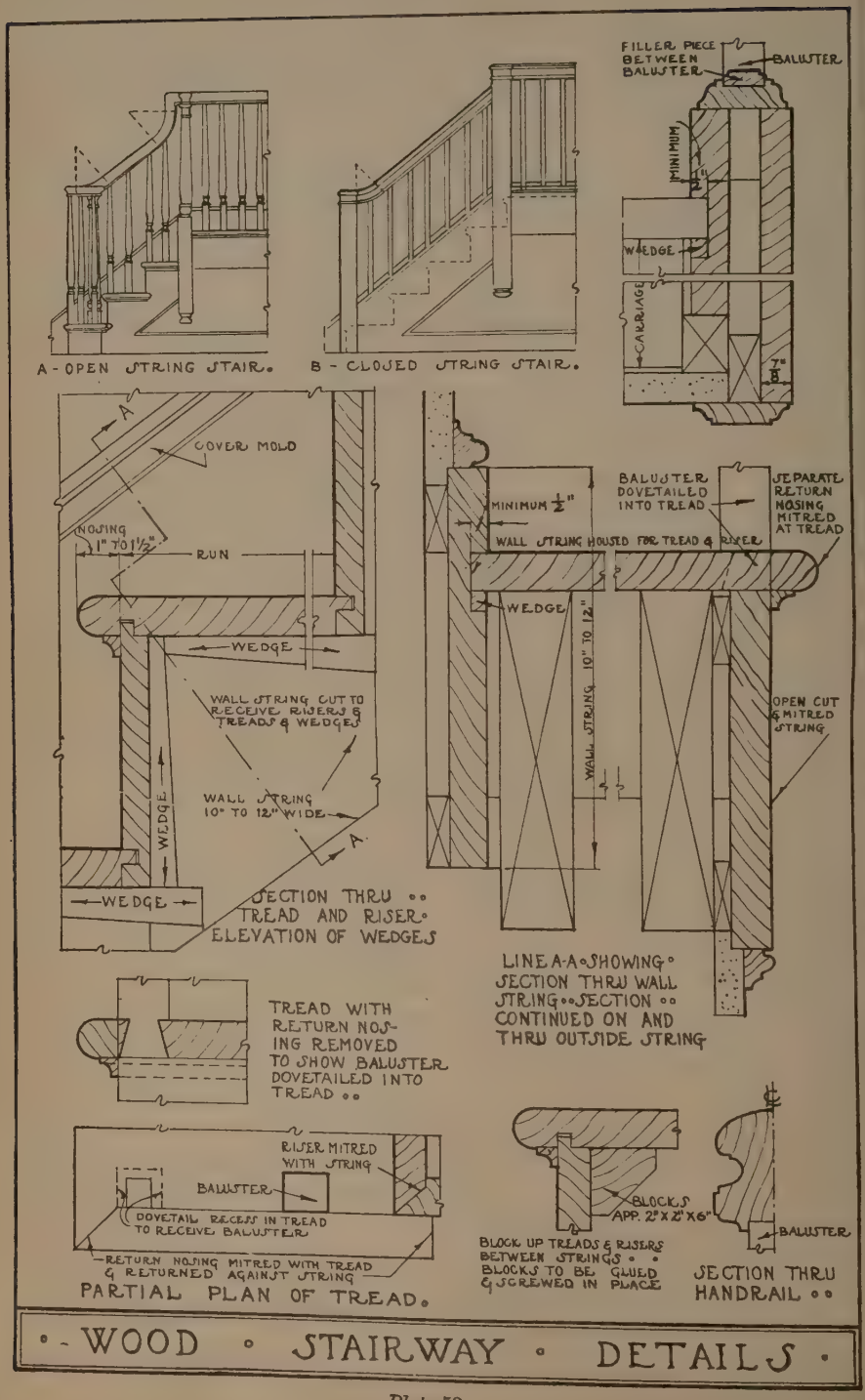

A - OPEN STRING STAIR.
B - CLOSED STRING STAIR.
FILLER PIECE BETWEEN BALUSTER
BALUSTER
MINIMUM
WEDGE
CARRIAGE
COVER MOLD
NOSING 1" TO 1½"
RUN
WEDGE
WALL STRING CUT TO RECEIVE RISERS & TREADS & WEDGES
WALL STRING 10" TO 12" WIDE
WEDGE
WEDGE
SECTION THRU TREAD AND RISER ELEVATION OF WEDGES
MINIMUM ½"
BALUSTER DOVETAILED INTO TREAD
SEPARATE RETURN NOSING MITRED AT TREAD
WALL STRING HOUSED FOR TREAD & RISER
WEDGE
WALL STRING 10" TO 12"
OPEN CUT & MITRED STRING
LINE A-A SHOWING SECTION THRU WALL STRING SECTION CONTINUED ON AND THRU OUTSIDE STRING
TREAD WITH RETURN NOSING REMOVED TO SHOW BALUSTER DOVETAILED INTO TREAD
RISER MITRED WITH STRING
BALUSTER
DOVETAIL RECESS IN TREAD TO RECEIVE BALUSTER
RETURN NOSING MITRED WITH TREAD & RETURNED AGAINST STRING
PARTIAL PLAN OF TREAD.
BLOCKS APP. 2"X2"X6"
BLOCK UP TREADS & RISERS BETWEEN STRINGS BLOCKS TO BE GLUED & SCREWED IN PLACE
BALUSTER
SECTION THRU HANDRAIL
WOOD STAIRWAY DETAILS

Plate 53.

All kinds of newels should be made of built-up and glued-up material, to add strength and to eliminate warping, in the same way that these two much desired ends are gained in plywood or in door cores.

Further to strengthen a balustrade of this character, it is desirable so to handle the tread that it will take the dovetail turned on the ends of the balusters. This is accomplished by routing out the tread, inserting the dovetailed balusters, and applying over the end of tread the nosing which completely covers this construction and results in showing no end grain whatsoever.

Forms such as the volute and goosenecks on straight rail are bolted together with invisible bolts and glued, forming a joint that is extremely difficult to find. All of this is done in the exact center of the rail and the attached members, the bolts being turned up with burrs which can be reached through a hole in the bottom of the rail. This hole is later plugged with corresponding wood and, being on the bottom of the rail, is never seen.

Wall stringers should be beveled where they meet the risers, so that no butt joints exist, and they should be routed to receive both treads and risers and secured in place by wedges and glue, thus eliminating the use of nails.

Volutes and goosenecks are developed from a parabolic curve and can be adapted to any rise and run of stairs. Goosenecks thus produced are delivered long, so that they may be cut off at the appropriate point to meet the straight run of the rail at the correct angle. Such volutes also run to their scroll on a parabolic curve rather than at a straight angle, which results in a graceful and correct form.

Square, built-up newels such as that shown in *b*, *Plate* 53, are made with a lock-mitred joint at the corners, which eliminates the use of nails and produces a construction that is permanent so far as the joint is concerned. This is a glue joint, detailed in *Plate* 56, which provides a maximum amount of glue area and which would actually hold together even without the glue, on account of the peculiar contour of the adjacent members.

Stair rail and other curved parts which correspond with rail, are built up of from three to five plys by a method similar to that used in building up stair newels, in order to insure straightness and increasing strength.

Cabinetwork.—The mill products which usually fall under this classification include such items as china cases, kitchen dressers, linen cases, medicine and bathroom cabinets, telephone cabinets, broom closets, drawers and tray cases, and built-in dressing cabinets. The construction of these items as stock cabinetwork is designed primarily to fill the wants of the average home builder, whereas more pretentious installations of this character are made to special detail and, of course, at an increased cost.

Plates 54 and 55 illustrate, respectively, a kitchen cupboard, and a linen case.

As in all other wood-product items, the selection of wood thoroughly seasoned and without defects in any exposed part is the standard to which these items are produced. Some slight sound defects not impairing the appearance or durability should be permitted, but only in cabinet backs and undersides of shelving. All face material should be closely matched; as a result of this precaution and the restrictions imposed above, quality items of this kind with closely matched material on the faces show a good finishing surface, carefully sanded, and the seasoned material reduces almost to elimination the warping, shrinking, swelling, and checking.

All small moldings should be self-returned at the corners, instead of being mitred. This practice prevents open corners or loose small pieces caused by any wood movement. Full mortise-and-tenon joints should be used in cabinet faces and doors, so as to produce strong, durable faces as well as doors with all small pieces fixed securely. Such parts cannot come loose, turn, or fall apart. The use of stub tenons may be found in lower-quality, built-in material, but it is a practice that does not return the value which the ultimate buyer should have.

The lock-mitred joint previously referred to should be used wherever possible in all mitred corners and pilasters. Since this joint cannot open up, it makes the matching of the grain at the corners possible, shows no end wood, and eliminates unsightly nail holes.

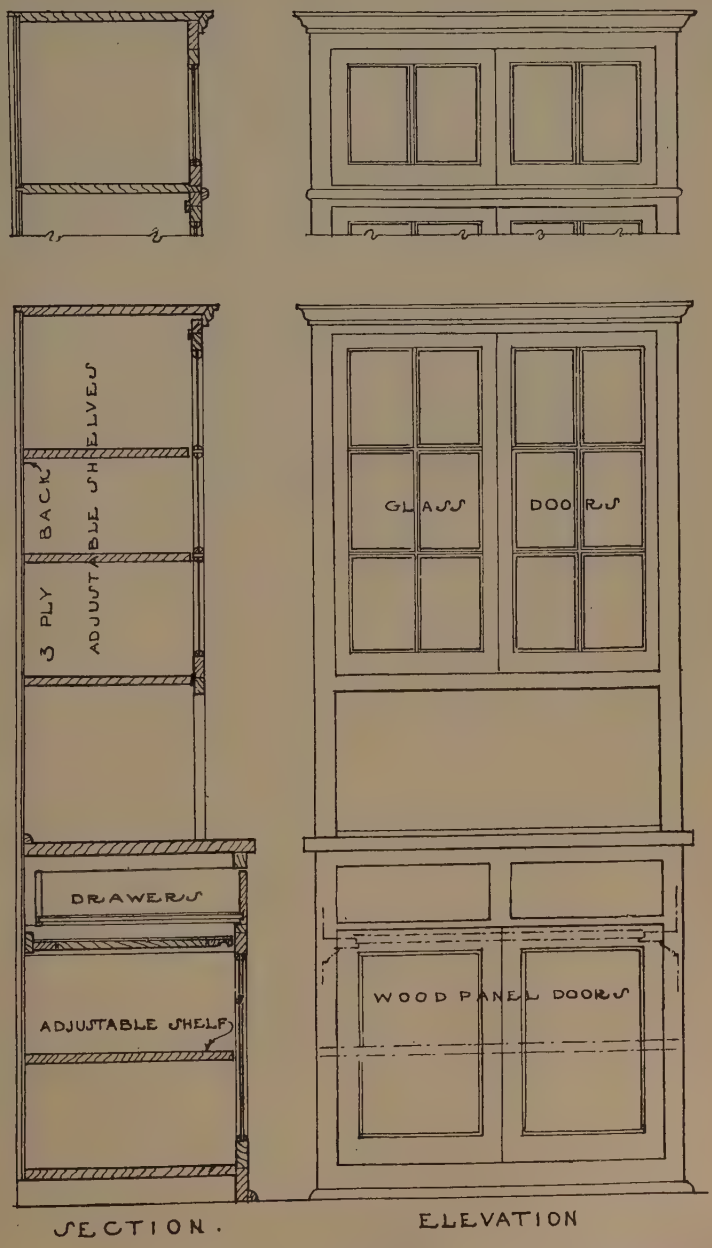
The best practice demands that the cabinet faces finish $1\frac{1}{16}$ in., since a more than usually sturdy construction results, and the thicker face resists a tendency to warp.

Cabinet backs and drawer bottoms should be at least three-ply veneered construction, giving these important parts extra strength and resistance to wood movement.

Drawer backs and faces should be dovetailed to the sides, since such practice absolutely prevents these parts from failing under the strain of pulling.

In bookcases, where strength is necessary because of the nature of the piece, and where for design purposes thick material is required, the best practice indicates a tendency toward three-ply construction in those parts. This gives greater strength and eliminates the tendency toward warping which usually would be highly developed in a solid hardwood board, particularly of 1-in. thickness or greater.

To eliminate the "sticking" of drawers, a common annoyance, it is well to taper them at the back, making them about $\frac{1}{8}$ in. narrower there than at the face. This gives a flush joint at the face of the cabinet, which is the only point where the drawer really closes tightly in the opening.



TYPICAL · KITCHEN · CUPBOARD.

Plate 54.

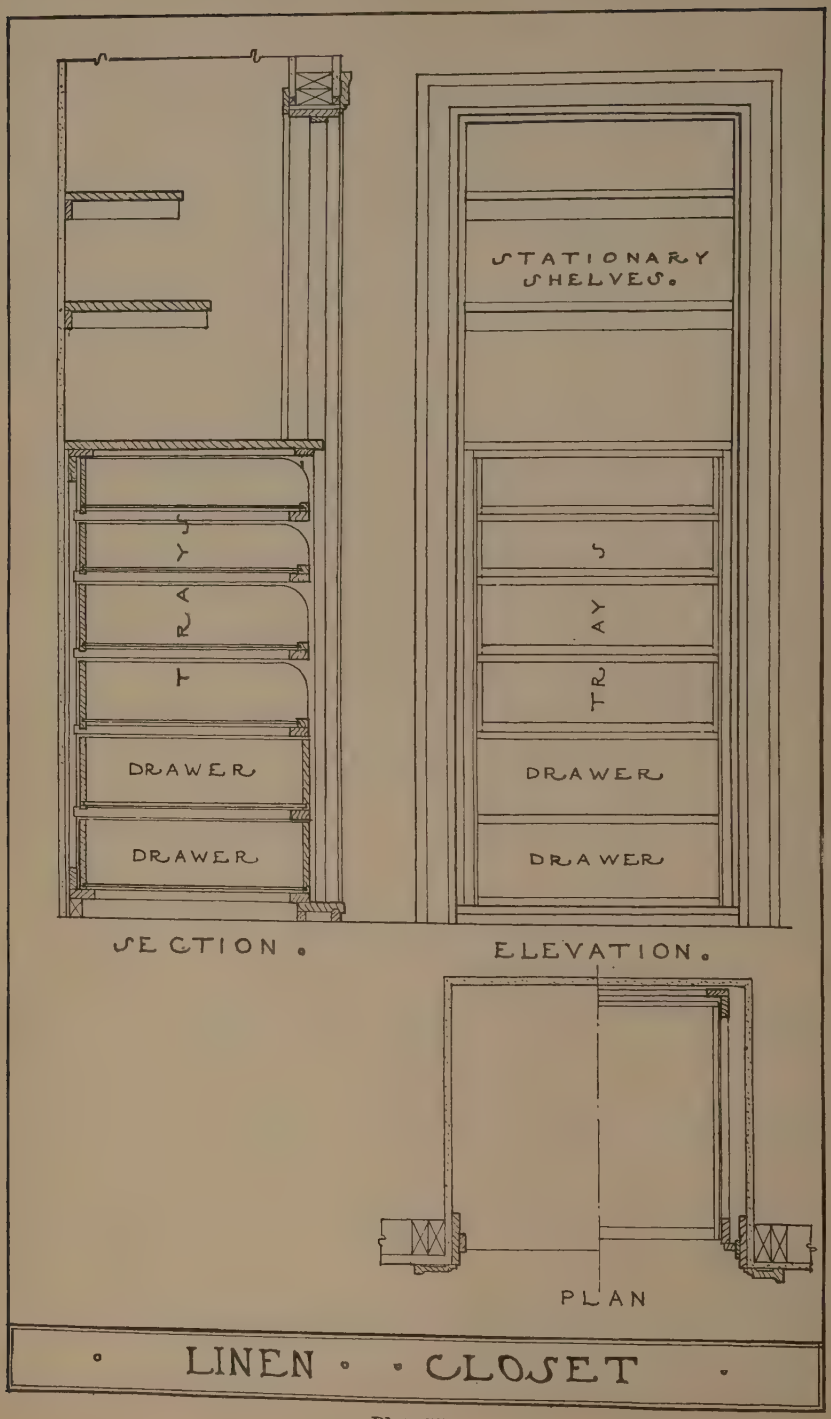

STATIONARY SHELVES.
TRAY
DRAWER
DRAWER
SECTION.
ELEVATION.
PLAN
LINEN · CLOSET

Plate 55.

The use of hardwood center guides for drawers, and the placement of a metal button in a guide notch at the bottom of the drawer back, provides a metal-on-hardwood sliding surface, prevents the jamming of the tapered drawers, and makes operation always easy and smooth.

By fitting the plywood drawer bottom into a groove on sides and front and back of drawers, a stronger drawer results, and the possibility of movement of the bottom panel is eliminated.

Adjustable shelves are used throughout the better lines of cabinetwork, being made adjustable by means of holes in the cabinet sides into which pins are inserted.

The use of cleated mitre joints rather than butt joints or plain mitres gives an extra-strong joint, permitting the end matching of the grain of the face in such forms as the bases of columns.

Careful machine sanding produces in the finished item a surface which minimizes almost entirely the necessity of hand sanding on the job.

MECHANICAL DETAILS

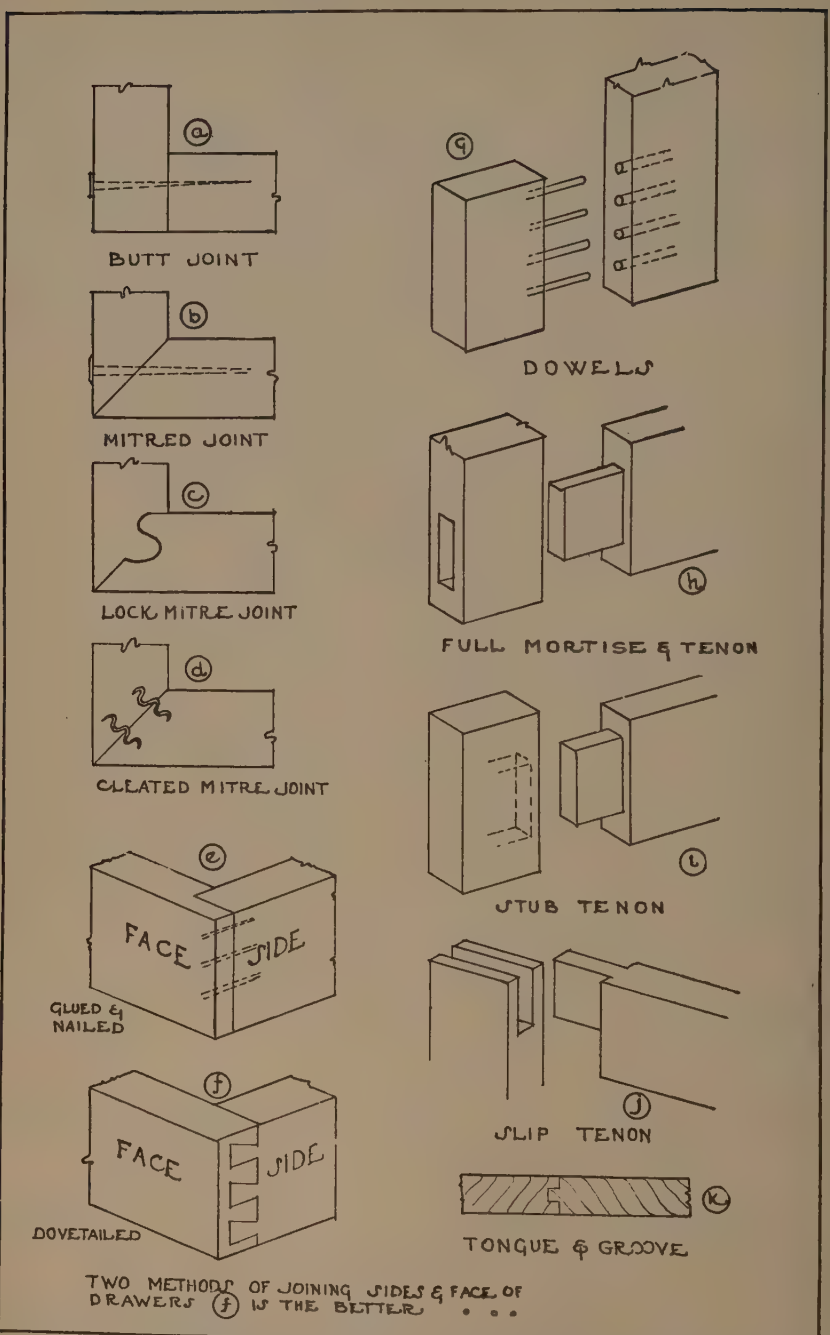
The several mechanical details which are important in the production of woodwork may be generally classified as joints, matching, gluing, and sanding.

Each one of these details contributes largely to the quality of the resultant product. When to these several divisions are added the consideration of proper kiln drying and proper machine speed for various operations, a picture of the important things to be watched by the producer of woodwork is presented. When the investment necessary to provide not only the actual equipment to carry out these various processes but also the testing equipment required to insure continuous and satisfactory operation of the different steps, is considered, it is realized very definitely that the better mill products are most likely to be those which come from manufacturers adequately equipped to maintain, to purchase, and even to produce machines for specific purposes, as well as to maintain the necessary personnel and materials incident to laboratory and experimental work.

Joints.—The various joints used in the construction of veneered door-core parts have been discussed elsewhere. These joints are usually of the tongue-and-groove type and have been found eminently satisfactory throughout years of commercial experience.

Recent tests, however, have shown that the dowel type of joint, using hardwood dowels, is satisfactory and that it may provide even a stronger joint than is provided by some of the mortised types of door.

The joint used in the building up of plywood and in the building up of material for stair parts such as newels and rail is simply a straight, flush planer-joint. These members are always of sufficient width to provide ample glue surfaces and, therefore, ample holding power in relation to their size and the work they have to do.



MISCELLANEOUS CABINET DETAILS.

Plate 56.

Aside from these two types, the various joints used in the manufacture of woodwork may be divided into the following classes:

1. Angle joints.
2. End-to-edge joints.
3. Edge-to-edge joints.

In *Plate* 56 are shown three types of joints which are used in millwork, Fig. *a* illustrating the common butt joint, Fig. *b* the plain-mitre joint, and Fig. *c* the lock-mitre joint.

It seems hardly necessary to call attention to the superiority of the joint covered by Fig. *c* as compared with the other two. In the butt joint shown in Fig. *a*, often used in cheaply constructed material, one face of the joint shows the edge grain of the wood, greatly impairing the appearance of the piece.

With this construction, warping often forces out the retaining nails and opens the joints.

The plain mitre, which is held by glue in addition to finishing nails, presents a better appearance, but, like the butt joint, it lacks the required strength.

The lock mitre or the cleated joint shown in Fig. *d* is a great improvement over either of the other two. The lock-mitre joint offers three distint advantages: (1) a solid joint which will not open even under extreme pressure; (2) a joint showing no edge grain; (3) a joint which makes it possible to match the grain of the members forming the angle.

There are places, of course, where this lock-mitre joint is impractical, as in columns and pilaster bases. A cleated mitre is produced through the use of glue and corrugated-metal cleats.

This joint is far stronger than the ordinary glue-mitre or butt joint and permits careful matching of grain. As a general thing, the sections of wood so joined are thin, and the possible shrinking and swelling of properly kiln-dried and selected material eliminates largely the maximum movement of wood. The glue and the corrugated cleat seem satisfactorily to overcome wood movement, under normal and fair care.

Another form of angle joint, the dovetail, is advisable when the manufacturer is faced with the problem of joining the facing and back to the sides of drawers and, again, where balusters are to be attached or fastened to stair treads. Figure *f* illustrates the dovetail joint as applied to drawer construction. Its value over a common method, shown in Fig. *e*, is at once apparent.

Joining an End to an Edge.—In ordinary practice, there are two joints used to join the end of one member to the edge of another. In members large enough to take more than one dowel, the dowel joint is the stronger.

Obviously, a joint is not useful in joining the fine part of cabinet fronts if but one dowel can be used, for a single dowel would not keep the joint from working loose and allowing one of the members to turn on the axis

formed by the dowel. Because of the extreme difficulty of tenoning various sizes of small parts, it is common to find the dowel used in cabinet fronts and other places where such a defect will arise. For the most part, however, manufacturers confine the use of the dowel joint to the heavier members in which more than one dowel can be used.

In doors where the bottom rail is joined to the stile, it is well to use at least four dowels. The same is true of lock-rail construction. In intermediate rails and top rails, two dowels are sufficient, as a general thing. By following this practice, strength is provided where strength is necessary in a door.

Hardwood dowels are very much better than softwood dowels, because of their additional strength. The grooved dowel is the only practical one, since the groove (1) lets out the air at the bottom of the dowel pocket when the dowel is inserted and (2) lets out any extra glue which might keep the dowel from going into the full length of the opening.

A dowel with a compressed-air pocket behind it will tend to make an open joint, and one with too much glue at the bottom of the pocket will not form a tight joint.

The best practice requires: (1) that a maximum number of dowels be used to provide the greatest possible holding strength; (2) that no air pocket form at the base of the hole which receives the dowel; and (3) that there be no hard glue obstructions at the base of the hole to keep the joint from completely closing.

Dowel construction is indicated in Fig. *g*, *Plate* 56, whereas full mortised-and-tenoned construction is indicated in Fig. *h*, and the stub-tenoned in Fig. *i*.

Mortise-and-tenon joints are commonly used where the dowel is impractical. A full mortised-and-tenoned joint is eminently stronger than the stub-tenoned joint, and material so joined, though somewhat more expensive than the stub-tenon construction, is well worth the difference in price.

Figure *j* illustrates a slip-tenon joint, which, when properly pinned, as in the top rail of sash, forms an effective joint. It is generally used in this particular place because it has sufficient strength to stand under all reasonable tests; it has given long effective service, and is economical to produce.

Joining Members Edge to Edge.—Tongue-and-groove joints of various types are used for joining members edge to edge and have proved so eminently satisfactory under test that no definite attempt has been made to find anything of greater value. This joint shown in Fig. *k* therefore, is used in building up of wide members of any kind as well as in holding together the core members wherever used in millwork construction.

Various other methods of locking cores together have been attempted, but none seems to be more satisfactory than this simple joint, which

allows plenty of holding space for the rather coarse-textured casein glue used in this type of construction.

Under test, joints of this character have stood up even after the wood itself has sheared, and it is uncommon to have joint failure prior to failure of the wood cells themselves.

Matching.—When large wood surfaces are necessary in woodworking, it is far more practical, and at the same time less expensive, to produce them by building them up from smaller boards. These boards are tongued and grooved and glued together, and it is obvious that they must be selected for color and grain, if the finished surface is to be beautiful.

There are no rules, and no particular methods to follow, whether these surfaces are made up of solid boards glued together or are produced by matching veneers over a core. It is a problem that can be handled only by the individuals in charge of the operation. Material of this character, therefore, must be purchased from manufacturers in whom the purchaser has the utmost confidence. Certain companies have been particularly noted for their care along this line, and experience will dictate to the individual buyer the source of supply he should seek for work of this character.

Glues and Gluing.—The glues that are adapted for the gluing of wood are generally divided into five classes:

1. Animal glue produced in dry form, to be mixed with water and melted.

2. Casein glue, commonly sold in prepared form, requiring only the addition of water.

3. Vegetable glue derived from starches. These are mixed with cold water and alkalies, although heat is commonly used in their preparation.

4. Blood-albumin glues, which must be mixed from the separate ingredients just before use, since they deteriorate rapidly.

5. Liquid glues made from heads, skins, bones, and bladders of fish, which come in prepared form ready for immediate use.

Animal glue, usually referred to as *hot glue*, develops great strength and reliability in the higher grades. It is most suitable for hand spreading on irregularly shaped joints. The fact that it is not highly resistant to water is a drawback.

The property of casein glue that makes it most suitable for use in woodwork is its high moisture resistance, which enables it to perform satisfactorily under moist conditions. Casein glue, relatively, is new commercially, although it has been used long enough to determine definitely that it has more advantages than any other glue. Certain special casein glues have been developed by individual manufacturers, and certain other casein glues of good quality are available through government patents which belong to the people, and all of them serve well in the general practice of woodworking.

The vegetable glues have not found great favor in wood joint work, because of their lack of water resistance and the fact that they usually cause staining, particularly if used in connection with thin veneers. The fact that they set somewhat slowly is another disadvantage which has not been overcome.

Blood-albumin glues are particularly adapted to the gluing of plywood, and their use is practically confined to that field.

Liquid glues have, in general, properties similar to those of animal glue. The factors which limit their general use are high price and a lack of water resistance.

Generally speaking, the present vegetable and blood-albumin glues are veneer glues, while animal and casein glues are used for veneer and for glued joints. As between these two, the water resistance of the casein glue is of more importance than the freedom from staining found in animal glue. Casein glue is a cold glue, and through the last few years of experimentation by the entire industry has been developed to a very high point of water resistance and an almost total elimination of staining. It is, therefore, a very definite conclusion that casein glue should be used in all woodwork forms where the woodwork is in any way affected by moisture or change in relative humidity.

Casein-glue test joints made of maple blocks with the grain running in the same direction commonly have a shearing strength of over 2,500 lb. per square inch, as developed in tests conducted by the Forest Products Laboratory of Madison, Wisconsin. This strength, being greater than the shearing-strength test of softwood, gives ample evidence of the strength of casein-glue joints.

One of the factors which has to be watched carefully in the gluing operation is the elimination of foamy glue. This sometimes appears when the glue is spread and sometimes during the mixing process when too high speeds are used or a too great length of time is taken in the mix.

Foamy glue is the result of a formation of dry spots in joints and is produced by air bubbles. It can be overcome by the addition of certain oils; but careful testing of spreading apparatus and mixing apparatus, and constant supervision of these functions, is necessary for a high-grade gluing operation. Again we come back to the responsibility of the maker and the importance of knowing the organization which is furnishing the material according to specifications or of their own standard make.

Irregularities of Sunken Joints.—Occasionally, sunken joints appear, as in particularly thick panels or in door stiles and rails. They seem to occur over the joints in the core stock and are apparent in the face of the veneer. Too rapid progress in the preparation of the core is the basic cause of sunken joints. The wood next to the joint absorbs moisture from the glue and swells. If insufficient time is allowed between the gluing of the joints and surfacing of the core, which is the next step in

manufacture, more wood will be removed at the joints because of the greater swelling there than at intermediate points. During subsequent drying and seasoning, greater shrinkage takes place at those joints, causing depressions. The careful woodworking manufacturer has remedied this trouble by extending the seasoning period between gluing and planing. Outstanding manufacturers make it a habit to redry the rough core, thereby reestablishing the correct moisture content before these rough cores are planed to receive the face veneers. Since the proper length of this drying varies with the thickness and species of wood, and with atmospheric conditions, it is a problem for the kiln-drying expert and can be satisfactorily accomplished only in those plants which are properly equipped.

The Occurrence and Removal of Glue Stains.—Casein, as well as vegetable glues, contains certain chemicals which sometimes produce stains on certain kinds of wood. In common practice, the oaks are most often affected. This staining is due to the action of certain chemicals in the glue on the tannin and other constituents of the wood, an action which results in a certain stain that is inky in color. Glue stain, as a general thing in woodworking practice, appears by reason of the penetration of the glue solution through thin face veneer. Seepage seldom occurs if the veneer is more than $\frac{1}{20}$ in. thick and not too porous. The consistency of the glue in part determines whether it will or will not be squeezed through the wood under pressure. By decreasing the amount of water used with the glue, this penetration is minimized.

Occasionally, even the best manufacturers find their oak products affected by slight glue stains. It is not a defect, unless the oak is to have a very light natural finish.

Starved Glue Joints.—Failure of glue joints sometimes comes from what is called a *starved joint,* which is the result of the application of excessive pressure to a joint while the glue is still fluid. The use of casein glue tends to eliminate this condition, regardless of pressure. Starved joints are most likely to occur from the use of some animal and most blood-albumin glues.

The birches and oaks are commonly used in woodworking; they have open pores, which absorb glue from the spread so readily that they sometimes leave starved joints.

By using a thicker glue solution, or by allowing it to thicken on the wood prior to the time when pressure is applied, starved joints may be avoided.

Strong and Weak Glue Joints.—Glue joints which under test shear apart at the glue line indicate poor gluing. Those in which failure occurs in the wood itself are good joints and indicate that the glue joint is as strong as and often stronger than the structure of the wood itself. The three most common causes for failure of the glue joints are:

1. Glue used when too thin, so that it may be squeezed out of the joint.
2. Glue allowed to get too cold before pressure is applied.
3. Glue allowed to get too dry before pressure is applied.

It is evident that pressure and temperature are factors which must be considered in the gluing of a wood product. A definite relationship exists between these two factors, and it is only through constant testing and attention to these details that a manufacturer can produce a woodwork product that will stand satisfactorily the requirements put upon it by common use.

Sanding.—The main purpose of sanding any wood product is to obtain the right kind of base for the finish that it will be given in the process of decoration. Another purpose of sanding is to eliminate slight defects. A third purpose is to bring the material which is to be assembled with other material to the correct thickness. As an example, in the manufacture of doors, the stock from which the door parts are made is faced on one side, so that when the manufactured parts are put together there is one side—the face side of the door—in a single plane from which all thickness measurements are taken. When measured from this side, the variation in thickness of the different parts which are to be assembled is, of course, very slight—so small that the difference can be corrected by a drum-sanding operation. In the sanding operation in connection with doors, therefore, do two things: Prepare a surface for the painter's finish, and bring the door down to size.

It might be well here to say that $1\frac{3}{8}$- and $1\frac{3}{4}$-in. doors which are distributed generally and commercially, run from $\frac{1}{32}$ to sometimes $\frac{1}{16}$ in. thinner than the commercial size. This is a result of taking from $\frac{1}{64}$ to $\frac{1}{32}$ off each side of the door in the final finishing and sanding process.

Doors are sanded on a drum sander which carries three grades of paper, usually graded down from the coarser No. $1\frac{1}{2}$ through the No. 1 to the No. 0 sandpaper. The finest grade of the sandpaper mentioned really puts almost a polished finish on hard- and softwood alike.

Sash are sanded by the same type of machine and with the same grades of paper.

Molding and trim are sanded on their flat surfaces by drum sanders, and, in some instances, where specified, the contour or molded surface is molded with a brush sander. It is extremely difficult, through any brush-sanding process known, to retain exactly the contours of the moldings, particularly when they form sharp corners. But this is not a common specification.

In the case of cabinetwork, the various parts are sanded prior to assembling. Some of this work is done on drum sanders; other portions of it, on other types of sanders; after assembly, the cabinetwork is cleaned up by hand sanding, although vertical or belt sanders can be used on some

parts of the work to advantage. In this case, the very finest grades of paper are used.

Stairwork is sanded on various types of sanding machines, the turned parts being done entirely on brush sanders which are automatically operated. Types of machines generally used in the sanding operation for millwork are drum sanders where the sandpaper is tightly fixed to revolving drums; belt sanders, where the paper is carried as part of a belt and the pressure applied to the wood by a hand on the back of this belt; oscillating vertical sanders similar to the horizontal belt sander, except that the sandpaper itself is moved in a vertical plane. Disc sanders are used, which revolve in a vertical plane, and, similarly, elbow disc sanders revolve in a horizontal plane.

Automatic brush sanders for turned work operate much the same as the drum sander, except that, in the former case, the article to be sanded is revolved, whereas, in the drum sander, the drums carrying the sandpaper revolve, and the item to be sanded is pushed mechanically through the sander. On all other types of sanders, the pressure applied in the sanding operation is produced by hand, and, since it is variable, only the finer grades of paper can be used.

In the case of brush and drum sanders, the pressure, being mechanical, is constant, and the machines can be set to do a certain character and kind of work which will not vary during the actual sanding operation.

FIELDWORK

Grounds, or *ground strips*, as they are sometimes called, are used for a twofold purpose; they are intended, first, to provide a proper nailing surface or base for the trim or interior finish, and, second, to establish the thickness of the plaster.

They are applied to the studs or furring before the lath, and the lath is placed up to the *ground*. If properly applied, *grounds* help to insure a true surface for the plaster and make possible a close fit between the wood finish and the plaster, without having the finish drawn out of line in order to accommodate itself to irregularities in the plaster.

Grounds, especially where used in connection with ordinary lathed work, are approximately $\frac{3}{4}$ in. thick. With wood lath this provides for about $\frac{1}{2}$ in. of plaster between the face of the lath and the finished surface of the wall. Where special types of lath are used it may be necessary to increase the thickness of the grounds, and the recommendations of reputable manufacturers of the lath to be used should be followed.

When plaster is to be applied directly to masonry, grounds approximately $\frac{5}{8}$ in. are frequently all that is required.

Since the trim, base, or other finish is applied over and conceals the grounds, the width of the grounds may vary, but a usual width is about

1¼ or 1½ in. In the best class of work, one edge of the grounds is required to be beveled in order to insure the plaster being held in place.

In the application of trim, as in the case of a double-hung window, nailing surface on one side is provided by the side jamb of the frames; and on the other, by the ground strips. This is also the case with inside door frames, the door jamb corresponding to the side jamb of the frame in double-hung window construction.

All openings built to receive cabinetwork should likewise be grounded out, and the sizes of these rough openings so made should be clearly indicated on the plan.

In the case of plumbing up window frames, the studding on a wood building is usually set approximately 1 in. wider than the overall of frame, to allow ½ in. at least on either side to shim up and straighten up the frame. The same is true, roughly, in connection with inside door frames and jambs. The same thing also applies in providing rough opening measurements for the reception of case work.

Furring for the making of wall extensions usually takes the form of 2 by 2 or other similar material sufficiently strong to carry the plaster of other wall coating or covering, for, as a rule, walls are furred out simply for the purpose of providing a rough opening or finishing at the sides and top of built-in case work. They need no greater strength than will carry their own weight. There is no definite rule as to the material from which they are made.

Practically every manufacturer of woodwork lists in his catalogues the rough opening sizes of all the items he manufactures, which must set into such openings. Common practice in the setting of window and door frames makes it unnecessary to list this information, as the practice varies somewhat between contractors, although the general rule given above will hold in the vast majority of cases.

FINISHING AND PAINTING

A complete discussion of the subject of finishing and painting woodwork would require an entire book. Chapter VI on the use of paints and stains, discusses many important points, and it is suggested that those who are interested in the subject should secure full information in the form of pamphlets issued by reputable manufacturers of paint throughout the country. These pamphlets discuss the use of various paint, varnish, and lacquer products and their application to wooden surfaces.

For those who are interested in a more highly technical discussion of the subject, the following books may be referred to:

Zerr, George, R. Rubencamp, and C. Mayer: "A Treatise on Color Manufacture," J. B. Lippincott Company, Philadelphia, Pa., 1908.

Morrell and Wood, "Chemistry of Drying Oils," D. Van Nostrand Co., New York City, 1925.

BEARN, THEODORE: "Chemistry of Paints, Pigments, and Varnishes," Ernest Benn, Ltd., London, England, 1923.
TOCH, MAXIMILIAN: "Chemistry and Technology of Paints," D. Van Nostrand Co., New York City, 1916.
ANDES: "Drying Oils, Boiling Oils, etc.," Scott, Greenwood & Sons, London, England, 1901.
GARDNER, H. A.: "Laboratory Manual," Institute of Paint and Varnish Research, Washington, D. C.
LIVACHE and MACINTOSH: "Manufacture of Varnishes," Scott, Greenwood & Sons, London, England, 1911.
HOLLEY and TODD: "Mixed Paints, Color Pigments, and Varnishes," John Wiley & Sons, Inc., New York City, 1908.
JENNINGS, A. S.: "Paint and Color Mixing," Spon & Chamberlain, New York City.
GARDNER, H. A.: "Paint Researches and Their Practical Application," Institute of Paint and Varnish Research, Washington, D. C., 1917.
GARDNER, H. A.: "Paint Technology and Tests," McGraw-Hill Book Company, Inc., New York City, 1911.
HURST: "Painters' Colors, Oils, and Varnishes," J. B. Lippincott Company, Philadelphia, Pa., 1906.
GARDNER, H. A.: "Papers on Paint and Varnish," Institute of Paint and Varnish Research, Washington, D. C., 1920.
MORRELL and WADE: "Rubber, Rosins, Paints, Varnishes," D. Van Nostrand Co., New York City, 1920.
WOOD: "Rustless Coatings," John Wiley & Sons, Inc., New York City, 1905.
MORRELL: "Varnishes and Their Components," Henry Frowde and Hodder & Stoughton, London, England, 1923.

Several hundred bulletins on the raw materials and products entering into the paint and varnish and lacquer and color industries have been published by the Institute of Paint and Varnish Research, Washington, District of Columbia.

It is well, in passing, to treat the subject of raised grain, which occurs in all woods not properly kiln dried, or kiln dried to a moisture content too far below the average.

The machining of wood which contains too much moisture results in shrinkage after it has passed through the machine. As the wood gives off moisture, certain portions of the surface contract, leaving other parts raised above the average surface of the piece.

A similar situation can arise through a too free use of water stain by the painter. In other words, when stain has been applied too freely it is assimilated by the surface of the wood, and later, when the moisture leaves the wood, the grain stands out, owing to shrinkage of the average surface.

No definite rule can be laid down as to the handling of water stain, the ability and reputation of the finisher being the best guide to the correct handling of matters of this kind.

This situation obtains on both solid and veneered surfaces. More care must be taken with water stain on the veneered surface, however,

since there it is possible with some stains to set up an action in the chemicals of the glue. But this does not occur when the services of an expert wood finisher are secured.

This same situation in connection with the use of water stain is brought about where excessive sanding has reduced the thickness of the veneer materially, giving the water stain just that much more chance to get into intimate contact with the glue line. These things are mentioned as factors which should be carefully guarded against and taken into consideration in any finishing that is to be done.

Occasionally, in softwoods, where the surface of the wood itself seems perfectly free from defects, resin ducts may be located very close to the surface. As changing conditions of heat obtain, this resin sometimes shows through paint. In the majority of cases, where these ducts are near enough to the surface to be recognized by the expert painter, shellac is used over that particular area and allowed to dry thoroughly, previous to the application of the first coat of paint.

In some other softwoods, where there is an abundance of sap, the sap causes discoloration after the paint is applied. Sugar pine is one of these woods, and while it is not considered a commercial defect, because it cannot be noted, it sometimes causes trouble. particularly in connection with white woodwork.

There are a few general rules that should be applied to the care of woodwork immediately upon its receipt on the job and at the time of its installation.

As has been pointed out elsewhere, trim should be treated with a preservative coat on the back as well as on the face side just as soon as it is received. Frames, windows and sash, and all exterior items as well as interior woodwork should receive their first priming coat as quickly after delivery to the job as is possible. As between the manufacturer's plant, the retailer's warehouse, and the building under construction, there is naturally a considerable variation in the condition of humidity. This variation does not at once affect the wood, and if these priming coats are applied immediately after delivery, the amount of moisture taken up will not cause trouble, provided the material has been properly kiln dried.

Oftentimes in buildings under construction the humidity is much more severe inside than outside the building. This is something not commonly known, and more attention is given to priming coats on the material which enters into the construction of the exterior portions of the building than to that on the interior, whereas the reverse should be the case.

If precautions are taken to see that all woodwork is primed with an equal amount of material on all sides of each piece, practically perfect performance will be insured.

Special attention should be called to the treatment of outside doors, particularly since they are subjected to varying moisture conditions on either side. These doors should be primed at once, and particular attention should be given to the top and bottom rails. Often this precaution of closing the pores of top and bottom rails is taken care of at the time the door is delivered to the building. Later, however, in fitting the door, this protective coat is taken off, and it is a common practice to fail to replace it.

Thus, after the building is occupied, the edgewood of the top and bottom rail is allowed to stand open. It is subjected to difference in conditions of humidity, the wood is allowed to take up moisture, and, after a sufficient time, regardless of the character of the wood and the glue used, it will deteriorate at the glue line.

This results in loose veneer at the top and bottom of doors. Similar action takes place in solid stiles and rails, tending to distort them, since they are subject to more wood movement and absorption of moisture than the veneered stile and rail. The result is trouble with shrinking and swelling, which is extremely aggravating. The shrinking and swelling of the solid stile door is greater than that of the veneered product. In either event, these items should be carefully protected against the possibility of moisture assimilation at the places mentioned.

Where its use does not conflict with the finish desired for a particular item of woodwork, a mixture of white lead and oil is perhaps the best material to use for the protecting coat (see p. 194).

HARDWARE

The proper size of pulleys and weights is, of course, determined by the weight of the sash or window which the sash weights are designed to balance.

Commercially, sash weights are made in standard sizes with variations of ½ lb.

Common practice dictates that on a double-hung window each sash should be balanced within a ½-lb. limit. In the case of a lower sash, the weight of the two sash balances together should be about ½ lb. less than the weight of the lower sash, since when the window closes (the normal position), the sash is held in the down position by this difference in weight; theoretically, eliminating the friction between the sash and the side jambs and parting stops, the opening of the window would require approximately an exertion of ½ lb. of upward lift.

The reverse situation is true in connection with the upper sash, since normally (in the closed position) the sash weights have to hold it up; the difference in the weight of the upper sash and the total of the two sash weights should be approximately ½ lb., thus requiring the exertion of ½ lb. of effort to pull the top sash down.

Weights of 1⅜ in., Two-light, Check Rail Windows

Glass size, inches	Opening size, inches	Weights, pounds		Glass size, inches	Opening size, inches	Weights, pounds	
		S.S.	D.S.			S.S.	D.S.
12 × 16	1– 4 × 3– 2	9		27 × 26	4–10	23	26
12 × 18	3– 6	10		27 × 28	5– 2	24	27
12 × 20	3–10	11		27 × 30	5– 6	25	28
12 × 24	4– 6	13		27 × 32	5–10	28	30
12 × 26	4–10	13		27½ × 24	2–7½ × 4– 6	23	25
12 × 28	5– 2	13		27½ × 28	5– 2	25	28
14 × 16	1– 6 × 3– 2	10		28 × 16	2– 8 × 3– 2	16	18
14 × 20	3–10	12		28 × 18	3– 6	18	20
14 × 24	4– 6	13		28 × 20	3–10	21	23
14 × 26	4–10	14		28 × 22	4– 2	22	24
14 × 28	5– 2	16		28 × 24	4– 6	23	25
16 × 16	1– 8 × 3– 2	10	12	28 × 26	4–10	24	27
16 × 18	3– 6	12	13	28 × 28	5– 2	25	28
16 × 20	3–10	12	14	28 × 30	5– 6	27	30
16 × 22	4– 2	13	15	28 × 32	5–10	29	31
16 × 24	4– 6	14	16	28 × 34	6– 2	31	33
16 × 26	4–10	15	17	28 × 36	6– 6	32	35
16 × 28	5– 2	16	18	30 × 16	2–10 × 3– 2	17	19
16 × 30	5– 6	17	19	30 × 18	3– 6	19	21
18 × 16	1–10 × 3– 2	12	13	30 × 20	3–10	22	24
18 × 18	3– 6	13	14	30 × 24	4– 6	25	27
18 × 20	3–10	13	15	30 × 26	4–10	26	29
18 × 22	4– 2	14	16	30 × 28	5– 2	27	30
18 × 24	4– 6	16	18	30 × 30	5– 6	29	32
18 × 26	4–10	17	19	30 × 32	5–10	31	34
18 × 28	5– 2	18	20	30 × 34	6– 2	33	36
18 × 30	5– 6	19	21	30 × 36	6– 6	35	38
18 × 32	5–10	20	22	32 × 18	3– 0 × 3– 6	20	22
20 × 14	2– 0 × 2–10	11	13	32 × 20	3–10	23	25
20 × 16	3– 2	12	14	32 × 24	4– 6	26	28
20 × 18	3– 6	13	15	32 × 26	4–10	27	30
20 × 20	3–10	15	17	32 × 28	5– 2	29	31
20 × 22	4– 2	16	18	32 × 30	5– 6	31	34
20 × 24	4– 6	17	19	32 × 32	5–10	32	35
20 × 26	4 10	19	21	32 × 34	6– 2	34	37
20 × 28	5– 2	21	23	32 × 36	6– 6	36	39
20 × 30	5– 6	22	24	34 × 16	3– 2 × 3– 2	20	22
20 × 32	5–10	23	25	34 × 20	3–10	24	26
21 × 24	2– 1 × 4– 6	18	20	34 × 24	4– 6	27	30
21 × 28	5– 2	21	23	34 × 26	4–10	29	32
22 × 16	2– 2 × 3– 2	13	15	34 × 28	5– 2	31	33
22 × 18	3– 6	14	16	34 × 30	5– 6	33	36
22 × 20	3–10	16	18	34 × 32	5–10	34	37
22 × 22	4– 2	18	20	34 × 34	6– 2	35	38
22 × 24	4– 6	19	21	34 × 36	6– 6	37	40
22 × 26	4–10	20	22	36 × 20	3– 4 × 3–10	25	27
22 × 28	5– 2	21	23	36 × 24	4– 6	28	32
22 × 30	5– 6	22	24	36 × 26	4–10	31	34
22 × 32	5–10	24	26	36 × 28	5– 2	32	35
24 × 14	2– 4 × 2–10	12	14	36 × 30	5– 6	35	38
24 × 16	3 2	14	16	36 × 32	5–10		39
24 × 18	3– 6	16	18	36 × 24	3– 4 × 6– 2		40
24 × 20	3–10	17	19	36 × 36	6– 6		41
24 × 22	4– 2	19	21	40 × 24	3– 8 × 4– 6		34
24 × 24	4– 6	20	22	40 × 26	4–10		36
24 × 26	4–10	21	23	40 × 28	5– 2		37
24 × 28	5– 2	23	25	40 × 30	5– 6		40
24 × 30	5– 6	25	27	40 × 32	5–10		42
24 × 32	5–10	26	28	40 × 36	6– 6		46
24 × 34	6– 2	27	30	40 × 40	7– 2		49
24 × 36	6– 6	28	32	42 × 26	3–10 × 4 10		40
26 × 14	2– 6 × 2–10	13	15	44 × 24	4– 0 × 4– 6		36
26 × 16	3– 2	15	17	44 × 26	4–10		39
26 × 18	3– 6	17	19	44 × 28	5– 2		41
26 × 20	3–10	19	21	44 × 30	5– 6		43
26 × 22	4– 2	20	22	44 × 32	4– 0 × 5–10		46
26 × 24	4– 6	21	23	44 × 36	6– 6		50
26 × 26	4–10	23	25	44 × 40	7– 2		53
26 × 28	5– 2	24	27	48 × 24	4– 4 × 4– 6		40
26 × 30	5– 6	26	29	48 × 26	4–10		42
26 × 32	5–10	27	30	48 × 28	5– 2		44
26 × 34	6– 2	29	32	48 × 30	5– 6		46
26 × 36	6– 6	31	34	48 × 32	5–10		48
27 × 20	2– 7 × 3–10	20	22	48 × 36	6– 6		53
27 × 22	4– 2	21	23	48 × 40	7– 2		58
27 × 24	4– 6	22	24	52 × 26	4– 8 × 4–10		50

RELATIVE SIZES OF SASH CORDS, WEIGHTS, AND PULLEYS

Diameter of cord, inches	Feet per pound	Suitable for weights, pounds up to	Allowable minimum diameter of pulley, inches
3/16	66	5	1½
7/32	55	12	1¾
¼	44	20	2

In the table are given the weights of the various sizes of two-light, double-hung, check-rail windows of 1⅜-in. thickness, together with the weights of those windows when glazed with single- and double-strength glass. Since four sash weights are required to balance these two sash, the average weight of each sash weight would be determined by dividing the weight of the window by four. As an example, the weight of a 24 by 32 double-hung, two-light 1⅜-in. check-rail window is 28 lb. This would give a specification of two 7½-lb. sash weights for the upper sash and two 6½-lb. sash weights for the lower sash.

On account of the many sizes and types of windows which make for great variation in the size of the glass and the number of division bars and muntins, it is accepted practice to weigh up the windows to be balanced, although the sash weights required can, with average certainty, be specified prior to this operation.

To arrive at the approximate weight of 1¾-in. windows, add to the weights given in the table 25 per cent, or one-fourth, of their value.

A great many types of sash weights are on the market, some sectional in character, through which absolute balances of window weights may be obtained by adding small weights together to make up the desired total. When these are considered, complete information should be secured, so that the detail of the weight box may be made to take care of the variation of cross-section which exists among the various makes of such sectional sash weights.

Sash Cords and Pulleys.—The various factors which enter into the relative size of sash cords, weights, and pulleys may be determined from the table given. Frames widely distributed throughout the country are provided with pulleys of the maximum diameter shown in the table, thereby taking care of any average situation adequately.

There are many different qualities and types of sash cords; likewise many qualities and types of pulley. Sash cord is still more extensively used than either ribbons or chains, and a good brand of cord will probably never be entirely displaced by metal, for windows of ordinary size. Tests made at a leading technical school show that cords wear longer than chains, though naturally they have less tensile strength.

The best quality cord should be smooth and round and well glazed so that it has a smooth surface and consequently gets less wear or friction from the wheel of the pulley.

Since the life of any sash cord is materially increased as the diameter of the pulley over which it works is increased, frame manufactures, for the most part, are apt to use the maximum-reliable-sized pulley in connection with the balancing of all sash, using this as standard equipment in their frames.

There are in use a great many types of pulleys—cast iron and pressed steel being most generally used. The cast-iron pulley is rapidly being superseded by the pressed-steel type, because of certain advantages that are quite evident to the casual observer. The pressed-steel type of pulley can be economically produced in a form wherein the wheel is fully covered, and by that same covering the sash cord is confined on both sides of the pulley wheel and at its top, in a circular case. The sash cord runs over the pulley through this circular case and by reason of the case cannot possibly jump or jam. The pulley wheel of the pressed-steel type can be made absolutely smooth, thus eliminating wear on the sash cord and adding to the length of life of the entire window equipment. Different types of axles are used, the most efficient, measured from all angles, being the solid brass axle carrying the pressed-steel pulley wheel.

Finishing Hardware.—It is common practice to locate the knob and keyhole of a lock in the center of the face of the door stile. The one factor which controls the use of a given lock in a given door is the relation between the backset of that lock and the face width of the stile of the door.

This is a point that should be carefully considered in the selection of the door and the hardware to be used under a given condition.

The type of door, rather than the available hardware, seems to be the general controlling factor, but if a certain type and make of hardware is to be used, then investigation should be made as to the face width of the stile of the door to be selected. A careful examination of available locks, both of cylinder and bitted-key types, seems to indicate that lock manufacturers have provided a wider selection in those locks which have a backset of 2½ in. and wider, than in those of 2½ in. and narrower. Contrariwise, a development within the woodworking industry in relation to the face width of stiles of doors has shown a tendency toward decreasing this face width of stiles, in an attempt to get, first, a better design in proportion to the various door parts, and, second, extreme economy in the cheaper grades of doors.

This has resulted in some confusion, particularly on the part of the discriminating architect who desires a relatively narrow stile as compared with past standards in the millwork industry; and for this reason, it is recommended that careful study be given to the locks available for use in those doors where narrow stiles are specified or selected.

In the group of cylinder locks, the maximum number is produced with a 2¾-in. backset; practically the same number and choice is offered with a 2½-in. backset; next in point of number produced are those for a 2-in. backset; next, 1½ in., with 1¾ in. and 1-in. backset offering the smallest choice and confined almost entirely to use with French doors. In the bitted-key type of lock, the maximum number produced shows a 2¾-in., backset; next, a 2½-in. backset, with the remainder about equally divided among 2⅝- 2-, and 1½-in., 1¼-, 1¾-, 2¼-, 2⅜-in. backsets. Few types of 1-in. backset locks are available.

Those locks the backsets of which run from 2¾ to 3¼ in. find use in connection with specially designed doors. The face measurements of stiles of exterior doors run, for the most part, in dimensions 4¼, 4⅝, and 5 in., requiring 2-, 2¼-, and 2½-in. backset locks. French doors run in face measurement of stile 3⅝ in., and under, when good design is considered, requiring a backset of 1¾, 1½, or 1 in. Some French doors made in commercial quantity have a stile-face measurement of as high as 5 in. These are not in much demand, and hardware applied normally to the 5-in. exterior door stile may be used.

Such other hardware forms as flush bolts of the extension type, surface bolts, Cremone-type transom lifters, various classes of hinges, etc., present no problem as to a choice between available hardware and woodwork items to which they are applied, since standardized practice corresponds in both instances. Hardware for cupboard doors, drawer pulls, and similar items used in connection with cabinet work are of varying types and designs; corresponding sizes in millwork parts and hardware may be easily determined. Hardware for the operation of casement sash and garage doors is available through many manufacturers and shows a wide variation of types and sizes. The adaptation of each is a problem by itself and ishould be carefully studied in its application to the individual case.

SUPERINTENDENCE

The responsibility for superintendence divides itself into several phases; first, seeing that the specifications are fulfilled; second, seeing that the plans are carried out so far as dimensions are concerned; third, taking those preparatory and preventive measures which will insure lasting satisfaction after the materials are installed.

This discussion has only to do with the third division of superintendence, which is the recognition of defects and the insistence that precautionary measures be taken.

General Inspection and Installation

Doors.—Both exterior and interior doors should be fully sanded, with no raised grain or sander marks showing when delivered to the job.

Particular attention should be given to veneered doors, an examination being made at the time of delivery to be sure that possible rough handling has not loosened or split the veneer at edges or bottoms of doors.

The stile of the door which carries the lock should be beveled in a proportion equal to $\frac{1}{8}$ in. in 2 in., to insure easy action. This is necessary, particularly in the veneered type of door, in order that no friction whatsoever shall exist between the edge of the door (therefore, the edge of the veneer) and the jamb, and should be carefully watched.

Care should be taken that exterior door frames and interior door jambs are absolutely vertical. When they are not so set, material must be planed from the door in order that the square door may fit an opening which is off square. This necessarily will be noticeable if carried to the extreme and will destroy the fine elements of design in the door.

Before the hinges are applied to the hinged stile of a door, the door should be fitted almost exactly. It is common practice for carpenters to apply the hinges to a door stile and then take off all excess material from the lock stile, in order to make the door fit the opening.

Since practically all doors are made oversize in width, thus allowing about $\frac{1}{16}$ in. of material to be taken from the door in fitting the opening (for there is always some variation in the exact width of a frame opening), if this material is not evenly divided between the two stiles of the door when it is taken off one of them will be narrower than the other.

It has been noted that the difference in stiles of a fitted door has been as much as $\frac{1}{4}$ in. A difference of $\frac{1}{8}$ in. is very noticeable, and the only way to insure identical face-stile measurements in the finished and hung door is to see that the door is almost exactly fitted prior to the application of the hinges and mortising of the lock.

Unless exact work is performed in the application of the hinges to the door stile and to the door jamb, stresses are often set up which will cause warping in the door. The maker is usually blamed for any warping that takes place in a door; but in field observation by a leading woodwork manufacturer it has been definitely determined that in the majority of cases, door warping is due to a combination of conditions set up within the house, which includes jambs and frames being set out of plumb, hinges so set as to bring about a tension in a part of the door, and an incorrect condition of humidity.

A good-quality door can generally be determined by an examination of the character of its sanding and the quality of the coping of moldings either stuck, solid, or applied. These are details which can be readily determined even by superficial inspection.

Moldings and Trim.—Quality moldings may be recognized by their relative sharpness of contour, even machining, and the absence of raised grain or sander marks. With the exception of sound knots of small size in exterior moldings, the lumber should be entirely clear.

If the moldings are designed for natural finish, there are no allowable defects in interior moldings. A clear surface must be presented.

For painted work, however, slight blue sap stain is often allowable, although there are manufacturers of standardized moldings who would not consider the delivery of blue sap material. Elsewhere attention has been called to the difference existing between sap stain and fungi and how this difference can be determined.

Figure 98 illustrates one-, two-, and three-member bases, respectively, all applied to ¾-in. plaster grounds. The ¾-in. grounds are equal in

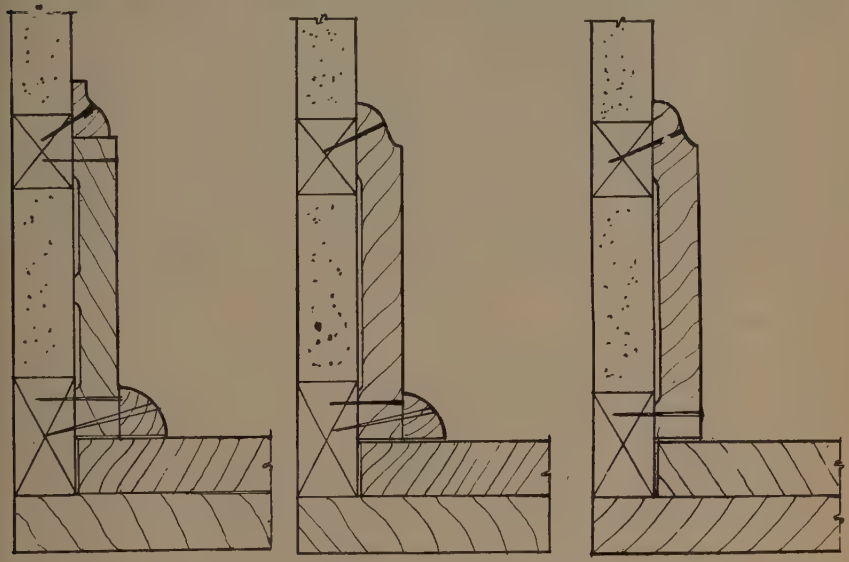


Fig. 98.—One-, two- and three-member bases.

thickness to the combined thickness of lath and plaster and have a dual purpose: (1) to provide an even surface to which the finished plaster coat may be leveled; and (2) to provide a sufficient and solid nailing surface for the base.

It will be noticed that the detail of the base shows that it is "backed out," which minimizes warping and twisting and makes it easier to "form" the base to the plaster surface.

Methods of applying the base, base shoe, and base mold are indicated. The base shoe should be nailed to the base itself rather than to the floor, as it is a part of the base finish. Should any settlement or movement of the walls or floor then occur, the base, whether it be of one, two, or three members, will act as a unit and will not open up.

Similar methods of placing grounds apply to paneling, chair rail and hook strips, and likewise to members of standing trim at doors and window openings.

Frames.—Frames with exposed parts of entirely clear lumber should be used, because the exposed parts are subjected to the elements continually and require an adequate paint finish for their protection. Such a paint finish can be obtained only on a carefully machined, even-textured surface, and anything but clear lumber naturally develops certain defects which, because of their ability to retain moisture, would hasten any deterioration and decay.

All frame parts should be carefully watched, to see that they member tightly. This is simply a precaution against open joints. Because certain frame details provide more chance for open joints than others, perhaps the most important point here is to see that the right frame is selected; after that, to be sure the machining is accurate.

In the installation of frames, it is very necessary to see that they are correctly plumbed and even more important to see that they are carefully and securely blocked up beneath the sill. It is common practice to place staging on the sills of frames, which brings upon the sill the weight of workmen and, in time, the weight of material. Unless the frame is carefully blocked up beneath the sill, it is almost impossible to avoid some distortion.

Because of the fact that a successful frame and window installation depends upon the tight fitting of storm sash, screens, and window sash, it is important that the sills be protected during the course of erection, so that they will not be marred or damaged.

Cabinetwork.—Very careful checking of rough openings against the rough-opening-dimensions of cabinetwork must be made as the work progresses. While manufacturers' listed rough-openings are dependable, it is well to check the actual rough-openings measurement against actual rough-openings requirements of the various pieces of cabinetwork just as soon as the openings are made and the materials delivered.

General Preventive Measures.—Attention should again be called to the most important item affecting woodwork performance—the maintenance of a right degree of humidity within the building during the process of erection and installation of woodwork forms.

Elsewhere has been mentioned the use of the hygrometer in as many parts of the building as may be necessary to insure the same general average humidity of approximately 55 per cent at a temperature of 70°. If this average is maintained, practically 100 per cent of woodwork troubles will be eliminated, provided, of course, that the woodwork is made from properly kiln-dried lumber and properly handled from the time it leaves the manufacturer's plant until it is brought to the job.

Regardless of the condition of humidity which prevails at the building, the tops and bottoms of all doors should be given a coat of white lead and oil as soon as they are delivered to the job.

The backs of all trim should be similarly treated, prior to erection. Perhaps the best results are obtained where it is common practice to apply filler and protective coats immediately upon the arrival of woodwork forms.

It is well to delay the hanging of all exterior doors just as long as possible, not only to keep them from being marred by the passage of material through the doorway but also to insure the correct relative humidity within the building. In order to correct relative humidity, exterior doors and windows should be left open at certain times; at other times, they should be closed. The use of temporary doors on the exterior is, therefore, suggested.

Blame for the failure of woodwork is often placed on the manufacturer, regardless of the care given to its production. Since conservative estimates credit millwork manufacturers with responsibility for but a small proportion of millwork failures, this is obviously unfair and may be corrected by owners, architects, contractors, and builders or whoever controls the maintenance of right conditions at the building, after the woodwork has been delivered.

References

Eastern Millwork Bureau..... New York, N.Y.
Florida Lumber and Millwork Association..... Orlando, Fla.
Millwork Cost Bureau..... Chicago, Ill.
Millwork Institute of California..... Los Angeles, Calif.
National Door Manufacturers Association..... Chicago, Ill.
National Woodwork Institute..... Chicago, Ill.
Pacific Northwest Millwork Association..... Aberdeen, Wash.
Southern Sash, Door and Millwork Association..... Atlanta, Ga.
Wholesale Sash and Door Association..... Chicago, Ill.
American Standard Moldings (7,000 series), Revised Simplified Practice Recommendation 16, U. S. Department of Commerce, Government Printing Office, Washington, D.C.

CHAPTER X[1]

HEAVY TIMBER CONSTRUCTION

In this chapter, up-to-date methods covering the use of wood in heavy construction are described and illustrated, and a few suggestions on the use of wood in steel-frame and reinforced-concrete construction are given. The information, which is based upon the wide experience of numerous engineers and architects throughout the country, touches on a variety of subjects. The field of heavy timber construction is greatly diversified, including many building types, such as mills, warehouses, and public buildings, besides an equal number of so-called *engineering structures*, such as roof trusses, bridges, pile and frame trestles, wharves and docks, and other similar construction where timbers 6 by 6 in. and larger are used. It is necessary, therefore, to deal mainly with fundamental principles having a unity of tendency and applying to the economic utilization of wood in the field of heavy timber construction, regardless of the particular type of structure for which the wood is to be used.

No attempt has been made to treat exhaustively all of the classes of structures ordinarily referred to as heavy timber construction. Numerous examples of good details are given, however. These details of recommended framing methods in a variety of structures, illustrating the practical application of basic principles, throw light upon the whole problem of correct wood utilization in this field, where the choice of wood is more limited than it is in light building construction and where engineering principles rather than empirical methods govern and control.

FRAMING IN HEAVY TIMBER

In heavy timber framing, the weakest point is the joint. Joints, therefore, should be designed to develop as nearly as possible the full strength of the connecting members. It is possible in designing timber trusses to compute correctly the size of the main structural members and then to detail the joints in such a general fashion that the safety of the structure is left in the hands of the framing carpenter. Such joints seldom fail, however, since the assumed working stress is only about one-third of the ultimate strength of the member.

This practice is in imitation of the practice in steel construction, where detailed connections are left either to the contractor or to the steel

[1] NOTE: Sizes and dimensions shown on drawings in this chapter are given only to enable the reader to visualize the proportions of the detail. They are taken from individual cases and have no general significance.

company. In either case, "contract" drawings are submitted to the architect or engineer for approval. Unfortunately this is not usually done in timber construction, and, as a consequence, timber joints are seldom detailed. They are simply made in the field by the carpenter.

There are excellent construction-detail standards for steel and concrete, but there are few for wood, unless those developed by railroads for bridges and trestles be so considered; and even these differ too widely to be classed as standards except under certain limiting conditions. The designer in wood must know theory, must have a knowledge of actual framing and erection difficulties, and must be familiar with sawmill and lumber-yard practices. The probability of having green lumber supplied must be anticipated and provided for, so that the joints designed will not be rendered inefficient by a shrinkage of the members.

Details of all connections except the very simplest should be shown on the plans and should be drawn to scale. Examples of good presentation are shown in this chapter. Carpenters sometimes try to scale distances with unfortunate results, when plans are not drawn to scale.

Joints in heavy framing are usually secured by means of bolts, screws, spikes, or straps and are either in tension or compression, such as splices in beams or truss joints connecting several members in compression and tension. Modern framing in the United States has practically eliminated the elaborate carpentry of housed joints such as the mortise-and-tenon, tusk-and-tenon, bridle, or cogging joints illustrated on *Plate* 57 in Figs. *a*, *b*, *c*, and *d*. Instead, dowels, bolts, straps, beam hangers, dogs, spikes, and nails are used. The cutting of timbers at joints is now usually limited to notching, as illustrated in Fig. *e*, to halving, as illustrated in Fig. *f*, or to the preparation of a toe joint in trusses, as illustrated in Fig. *g*.

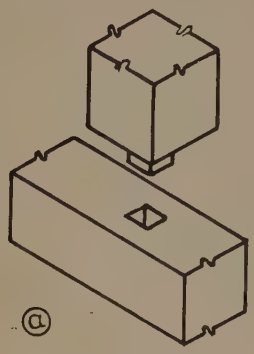
The kind of nails used to secure joints, unfortunately, is often left to the carpenter, with no instructions whatever regarding the size or number of nails required. The results of various tests on the lateral resistance of nails, and on both common wood screws and lag screws, are summarized in the following tables:

LATERAL STRENGTH OF WIRE NAILS

Safe Working Resistance to Lateral Shear

SIZE OF NAIL	SAFE LATERAL RESISTANCE, POUNDS $S = 8$ d.
6 d.	48
8 d.	64
10 d.	80
12 d.	96
16 d.	128
20 d.	160

S = safe lateral resistance or working stress.
d. = "penny" size of nail.



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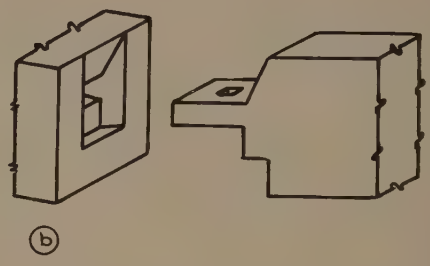
· MORTISE & TENON



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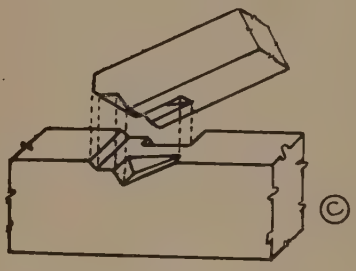
TUSK TENONED JOINT



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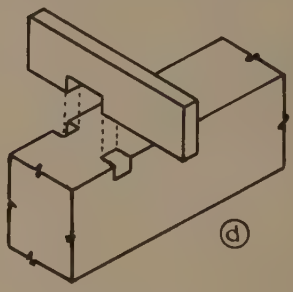
· BRIDLE JOINT



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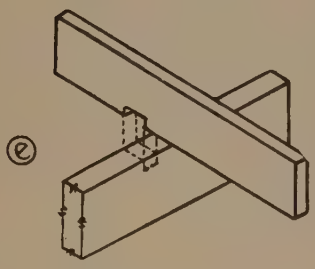
COGGING



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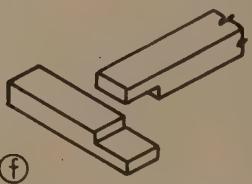
NOTCHING



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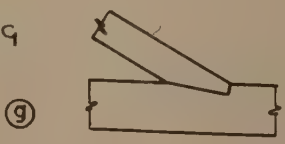
HALVED JOINT



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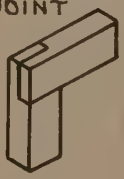
TOE JOINT



JOINTS · TYPICAL · DETAILS

Plate 57.

SAFE LATERAL RESISTANCE OF COMMON WOOD SCREWS

GAGE OF SCREW	SAFE LATERAL RESISTANCE, POUNDS
12	205
14	256
16	315
18	380
20	450
22	529
24	615

Safe lateral resistance $S = (\text{gage})^2 + 60$, approximately, for sizes up to 20 gage.

The action of a lag screw when subjected to lateral shear and flexure is similar to that of a nail but more like that of a common wood screw. Since the diameter of a lag screw in proportion to its length is considerably greater than that of a nail, the bending is less marked, and the resistance is dependent almost wholly upon the bearing strength of the timber. Lag screws should always be screwed into place, not driven.

LAG SCREW	LOAD CAUSING A SLIP IN THE CONNECTION OF 1/16 IN. POUNDS PER SCREW
Metal plate lagged to timber, inches:	
3/4 by 4 1/2	1,030
7/8 by 5	1,200
Timber packing lagged to timber, inches:	
3/4 by 4 1/2	900
7/8 by 5	1,050

The strength of bolted connections is probably the most vital subject in timber design, though it is a field in which only a few tests have been recorded. Numerous tests have been made on the resistance of spikes and screws to withdrawal from timber; but their behavior when subjected to lateral forces, producing bending and shear in the spikes or screws and compression on the timber, is still largely the subject of experiment.

Designers should give careful consideration to the size of "standard" washers, with bolts and rods. Washers designed originally for use with hardwoods are often used on softwoods, which have a lower compressive resistance across the grain. The bearing area therefore should always be carefully checked. The use of beveled washers is preferable to cutting the timber in order to secure bearing surface for the bolt or tie rod.

TENSION AND COMPRESSION JOINTS

There are various ways of joining timbers lengthwise. Joints of this kind are divided into three classes—lapped, fished, and scarfed. For joints in compression, the fished joint is the best. There are several such

joints in general use, and a right selection depends upon the importance of the joint, the cost, and the time allowed for erection.

Figure *a*, *Plate* 58, illustrates a common bolted-fished joint, in which the bolts should be kept 6 in. from the end of the timbers, on account of the tendency of the wood to check at the ends. The bolts should have a driving fit. This is the best type of compression splice. It is simple and has only one bearing surface.

The tabled-fished plate joint illustrated in Fig. *b* is an effective joint for compression and tension, but when this type of joint is used it is especially necessary to be sure that it is made of seasoned timber, as excessive shrinkage resulting from the use of unseasoned timber would overstrain the tables. Large-sized washers should be used with this joint, because the bolts are in tension. Steel plates and tables can be used to advantage where large stresses are to be transmitted, but in order to be satisfactory, they should be carefully fitted and thoroughly inspected.

Figure *c* shows a working detail of the application of a bar-and-tenon splice, in a bottom chord built up of two 12- by 12-in. timbers. The splices are staggered, and short bolts are used near the channels to resist tension set up by the bending couples. For varying-sized timbers, the tension bolts should be so proportioned as to develop the full tension in the timbers.

Figure *d* shows the use of keys in another type of tension splice. Here, seasoned timber, also, is essential, since even slight shrinkage will cause slippage in the joint. In timber work that is readily accessible, joints of this type should be inspected for shrinkage, and where necessary the bolts should be tightened. This is important, though it is generally ignored.

In work that will not be accessible for inspection and maintenance, only thoroughly seasoned lumber should be used.

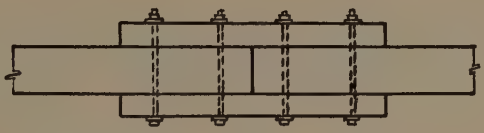
The compression splice known as a *half lap*, illustrated in Fig. *e*, is often used where the members are subjected to flexure in addition to direct tension or compression.

Figure *f* shows an oblique scarf joint which has greater flexural strength than the half-lap joint. This joint, however, is not so good in direct compression as the one shown in Fig. *e*, because the reduction in end-bearing area causes a tendency to open. Various modifications of the joints illustrated, incorporating keys or tables, are sometimes used; but, as a rule, the simplest connection is the best.

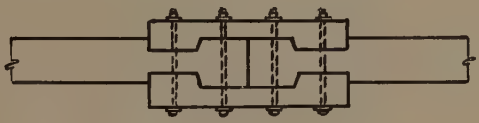
In general, where it is possible to secure chords of full lengths, so that joints may be eliminated, it is better to use the long timbers even at the expense of a considerable increase in the unit cost of the wood.

COLUMN CONNECTIONS

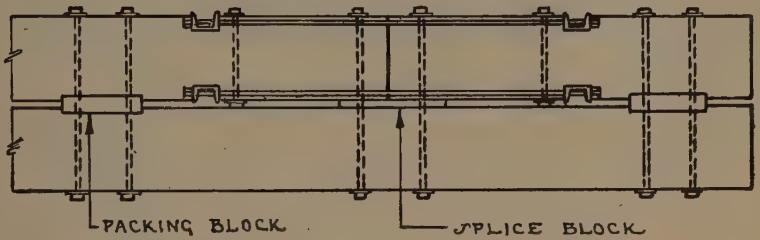
In a timber-framed building the size of a column is often determined by other considerations than allowable stress. Bearing-area require-

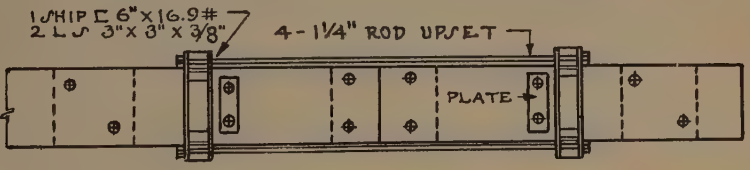


a. COMMON FISH JOINT



b. TABLED FISH JOINT





c. DETAIL OF SPLICE FOR BOTTOM CHORD

d. FISH JOINT - KEYED & TABLED

e HALF LAP

f OBLIQUE SCARF

JOINTS • TYPICAL • DETAILS.

Plate 58.

ments for trusses, girders, or beams which are to rest on the column, or a general minimum size of column to give sufficient fire resistance to the building, are frequently the deciding factors in the establishment of column size. The ideal condition of concentric loading is seldom realized except in the case of columns supporting floors or roof bays of uniform size; and unless care is taken in detailing the connections, the columns will usually be loaded eccentrically, with the subsequent development of bending stresses.

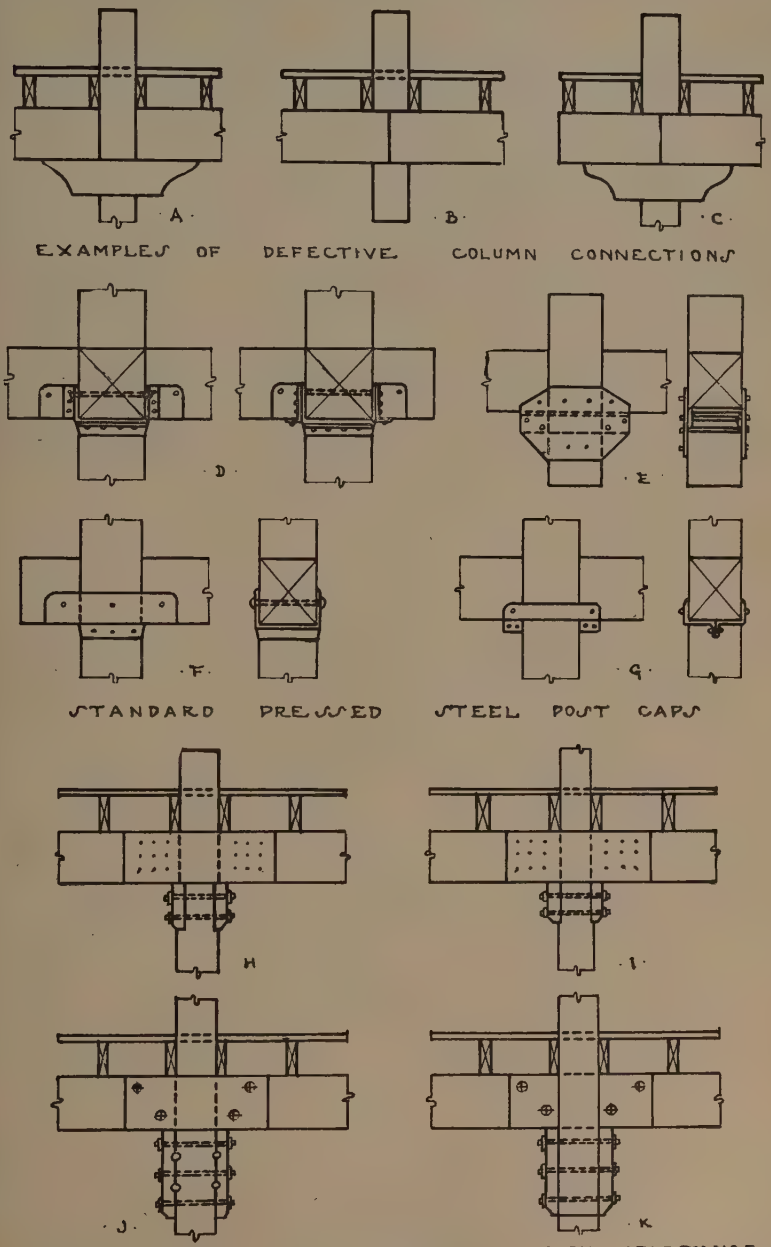
Compressive strength parallel to the grain is from two to four times as great as that perpendicular to the grain, so that, if a column is to be used economically, the bearing stress perpendicular to the grain of the floor beams or girders upon which the column rests will generally be greater than can be allowed with safety. Column action in a long column or post, however, may reduce the allowable working stress for end compression parallel to the grain, so that it will be nearly equal to the allowable stress in compression perpendicular to the grain; but when this situation prevails the economy of the design is doubtful.

By using a bolster to cap the columns, as shown in Fig. *a*, *Plate* 59, sufficient bearing for the girders will be provided, but the bolster must be so designed that it will not be overstressed perpendicular to the grain. The use of hardwood bolsters would reduce the required section of the bolster. When this detail is used, the shrinkage is only that of the bolster. Metal post caps are frequently used, to avoid this disadvantage in wooden bolsters. Cast-iron pintles resting on C. I. caps over the column below, as used in slow-burning, heavy timber construction especially, can also be used to advantage, for the girders then rest over the lower post, incasing the stem of the pintle and thus protecting it from heat in case of fire.

In the detail shown in Fig. *b*, it is almost certain that the girders have not sufficient bearing area to prevent the crushing of their fibers across the grain. This condition will produce settlement of the upper floors, which, added to the shrinkage of the beams themselves, will crack plaster walls or produce uneven floors. Settlement due to shrinkage is greatest when the construction shown in Fig. *c* is used.

Typical details of post-cap framing, utilizing standard pressed-steel post caps obtainable in the open market, are shown in Figs. *d*, *e*, *f* and *g*. Some of the more common of these post caps are the Duplex, Doetz, Van Dorn, and Falls. Prices of caps vary considerably, and it may be possible on large jobs to build up at a lower cost structural-steel post caps which will meet the requirements.

Four-way post caps are open to the objection that they result in unequal shrinkage where wooden girders are used, since the joists supported by the girders will be lowered to an extent that is equal to the shrinkage of the girder, while the joist or beam resting on the post cap



COLUMN CONNECTIONS · TYPICAL DETAILS

Plate 59.

will not be equally affected. This will occur even with the use of joist hangers, except that when hangers of the Duplex type are used the shrinkage will be only half that of the type of hangers which fasten over the top of the girders, because the Duplex joist hanger is secured to the girder by means of a circular nipple inserted into the girder at a point slightly above the center of the depth of the girder.

Where the absence of ceiling will permit, the details shown in Figs. *h* and *i*, *j*, and *k* will be found, on analysis, to be free from the defects of the connections shown in Figs. *a*, *b*, and *c*. The bolster blocks are housed or let into the lower post or bolted and keyed. In any case, a horizontal bearing surface is provided to take part of the vertical components and the section will be large enough to provide ample bearing for the girders.

Where the size of posts decreases with the succeeding stories, the trimming of the end of the lower post to the section of the upper post will ordinarily provide sufficient area for the bearing of the bolster blocks. The size of the bolts in Figs. *h* and *i* may be determined by taking moments about the center of the lower bolster bearing. Thus, in Fig. *h*, neglecting the effect of the lower bolts because of their short distance above the end of the bolster, the tension in the upper bolts may be found from the equation

$$T = \frac{Pa}{h}$$

where P is the reaction of the girder, a is the horizontal distance from the center of the upper end of the bolster to the center of the grain in the post, and h is the distance from the upper bolts to the lower end of the block. The bolts should be designed to take a tension equal to the reaction of the girder.

It will be noted that, in these details, the normal spacing of the joists has been modified at the post, to provide a joist at either side of the post. This is an inexpensive way to secure considerable stiffness in the building. In Fig. *k* the girders are shown tied together across the column by means of two wooden splice pads. The two sections of posts may be similarly tied together by the use of splice pads, with fillers under them of the thickness of the girder splices. A 1-in. thickness of girder pad will usually give sufficient tie, if it is long enough to give the required spiking or bolting area.

GIRDER AND BEAM CONNECTIONS

The least expensive and most satisfactory manner of supporting floor joists is to rest them upon the girders or beams. There is no device that is so satisfactory as putting the support directly under the load, without resorting to bending or shearing of metal. In buildings with enclosure walls of comparatively low cost, the extra height of building and the expense resulting from this form of construction will be justified. On the

other hand, in the case of a building with masonry walls several stories high, resting the floor joists on top of the girders or beams in place of attaching them by means of metal hangers may add 6 or 7 ft. to the total height of the wall. From the standpoint of cost of construction alone, therefore, the expense of the extra walls may be considerably more than the cost of the necessary joist hangers.

The danger of unequal shrinkage resulting from the use of hangers has been mentioned. On the other hand, even though all of the joists rest

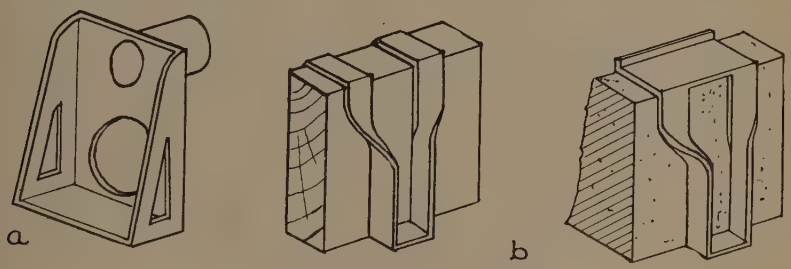


FIG. 99.—Types of joist hangers.

directly upon the girders, and the floors settle uniformly through shrinkage, they will not remain level, since the wall bays will drop at their inner ends the amount of girder shrinkage plus joist shrinkage, while the outer or wall ends will settle only the amount of the joist shrinkage. Where it is found necessary or is considered advisable to use joist hangers, special hangers may be designed, or some of the standard makes on the market may be used. The standard makes may be divided into two classes,

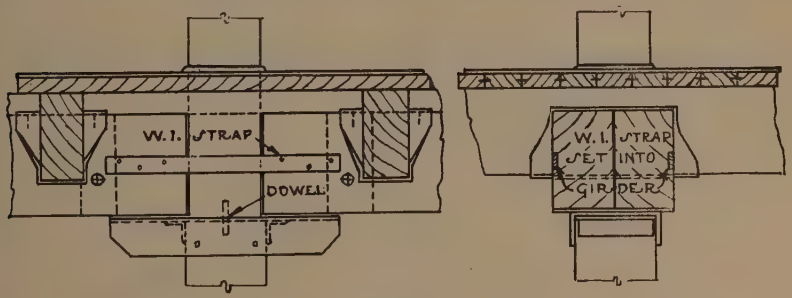


FIG. 100.—Steel post cap.

namely, those of the Duplex type, which have already been mentioned and are secured to the girders by means of an inserted nipple, and those which fasten by arms or straps that fit over the tops of the girders. The two types are illustrated in *a* and *b*, Fig. 99.

Joist hangers should not be used indiscriminately or without investigation as to their fitness for the particular case and their ability to withstand the particular load. The first point of weakness in a joist hanger of the

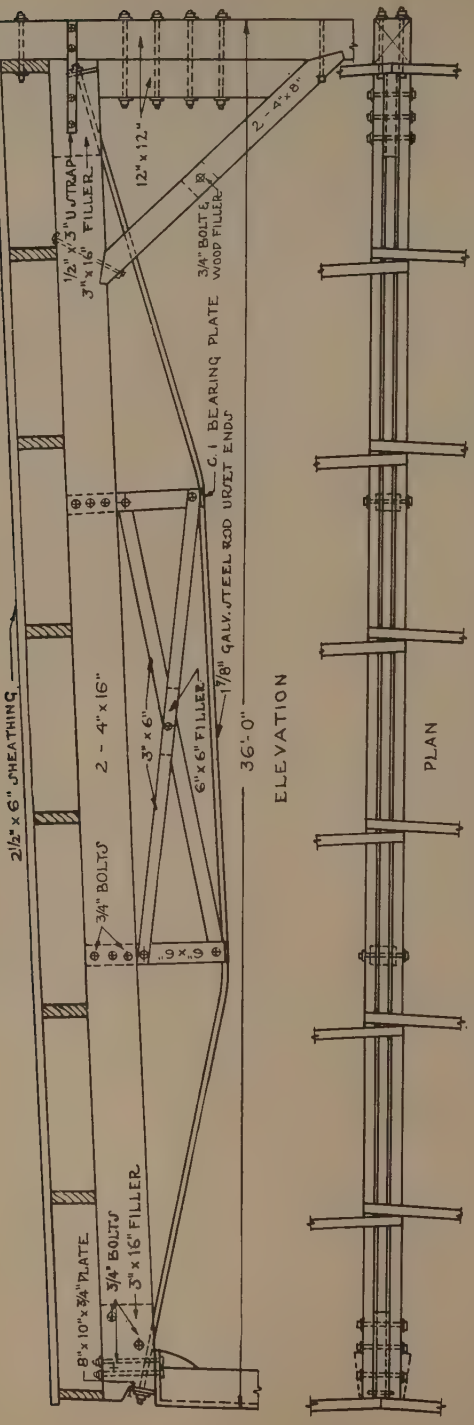


FIG. 101.—Roof truss on brick engine house, C.C.C. & St. Louis Railway.

stirrup type is the bending of the top strap and the crushing of the fibers on the joist side of the top of the girder. The second point of weakness is the bending of the bottom of the stirrup supporting the joist or the tendency to shear. The metal of a joist hanger does not fail by direct tension.

Structural-steel angles are frequently used to connect girders or floor beams to posts or columns. Figure 100 illustrates a method of securing floor beams to posts by the use of four angles and a bearing plate. The posts are doweled together.

Trussed beams are sometimes used in modified forms for roof girders. Figure 101 illustrates a working drawing of one of these trusses. The steel rods are framed in the ends of the beams and trussed underneath, so that the rods take tension; and the wood members, compression.

TIMBER JOINT PLATES

A patented joint which has come into favorable use is the *Midwest Bulldog*, illustrated in Fig. 102. Various applications of this joint are shown in *Plate* 60. It is made of cold-rolled steel and may be used as shown in the illustration. It furnishes a strengthening factor at the weakest point in timber construction, namely, the joint.

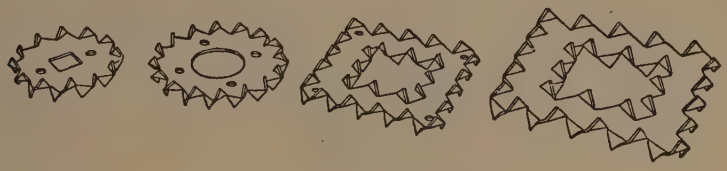


FIG. 102.—Bulldog joints.

The alligator joint illustrated in Fig. 103 is another patented device for strengthening bolted connections. It has been used successfully for several years in Norway and arrangements are being made for its manufacture and distribution in the United States. Numerous tests at

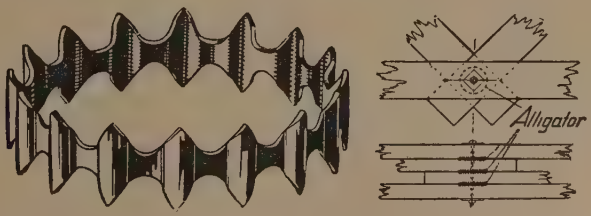


FIG. 103.—Alligator timber-joint connector. Showing application.

official testing plants in Norway indicate that an alligator-bolt connection will stand a stress from five to ten times greater than that withstood by a common bolt connection, before any noticeable displacement occurs.

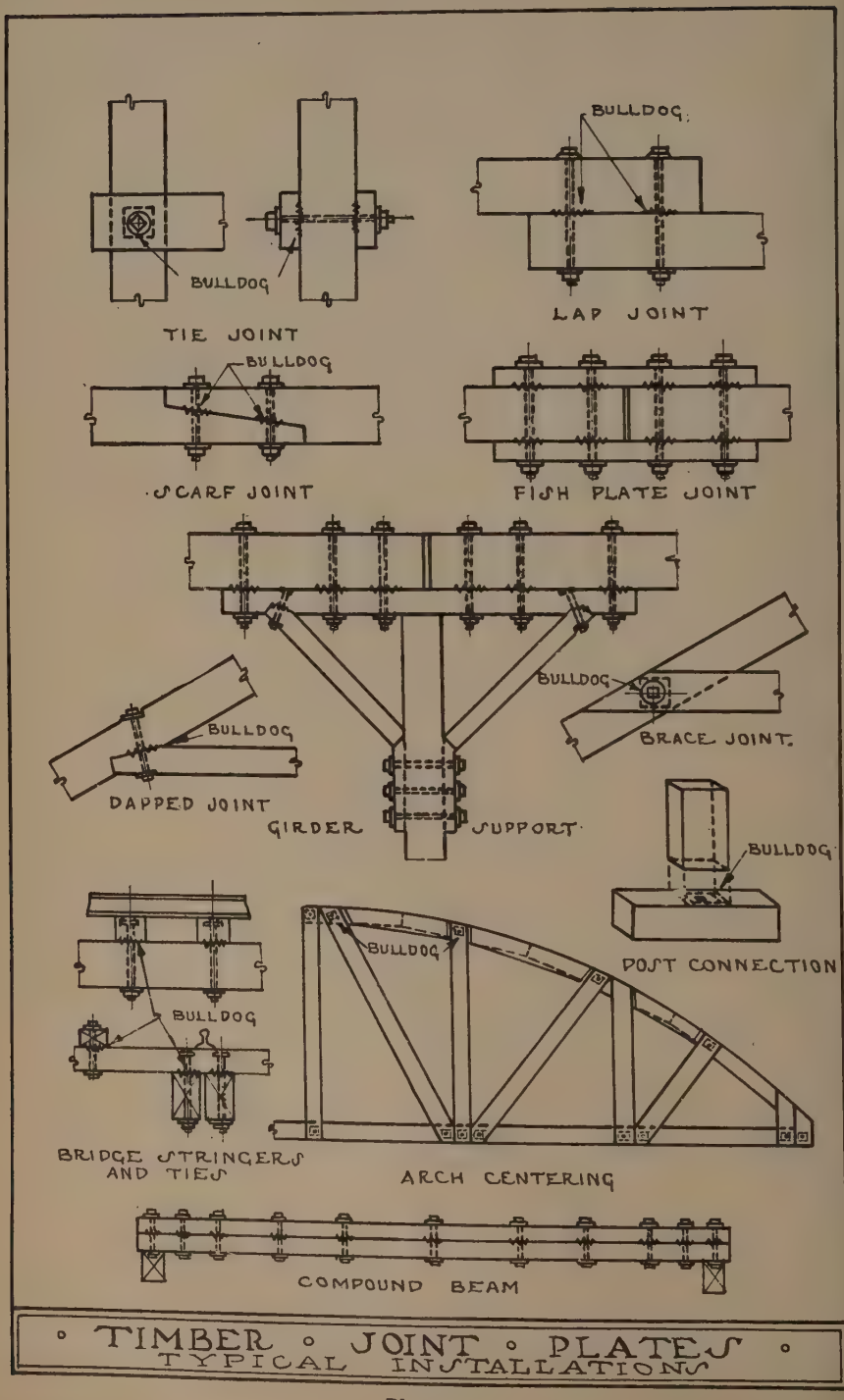

BULLDOG
BULLDOG
TIE JOINT
BULLDOG
LAP JOINT
BULLDOG
SCARF JOINT
FISH PLATE JOINT
BULLDOG
BULLDOG
BRACE JOINT
DAPPED JOINT
GIRDER
SUPPORT
BULLDOG
POST CONNECTION
BULLDOG
BULLDOG
BRIDGE STRINGERS AND TIES
ARCH CENTERING
COMPOUND BEAM
TIMBER JOINT PLATES
TYPICAL INSTALLATIONS

Plate 60.

SLOW-BURNING HEAVY TIMBER CONSTRUCTION[1]

Development.—The proportioning and detailing of slow-burning heavy timber construction, originally known as *mill construction*, is frequently neglected, because construction details have not been conveniently available in simple form. Heavy timber detailing has become a specialty, and those who specialize in this type of construction have designed such details as meet their special needs; but those who are only occasionally called upon to design buildings of this class usually improvise details as the need develops. Proper detailing is the essential feature in most types of construction; for, though the general design may be sound in every respect, unless the connections are properly proportioned and secured, lack of stability, and sometimes actual failure, results. The details shown in this book are based upon a careful field examination of recently erected buildings constructed in conformity with well-established design principles and upon details developed by firms of architects and engineers who have specialized in this type of construction. Details shown are intended only to illustrate principals of good construction. The sizes of all members must be computed to withstand the stresses to which they will be subjected in each particular case.

Standard mill construction, as originally practiced in the textile mills in New England, is not suitable for the space requirements of modern industrial processes. Close column spacing, though not objectionable in textile mills, seriously handicaps some other forms of industrial enterprise. In order to meet the demand for larger areas of floor space unobstructed by columns, two types of heavy timber construction are used: the semi-mill or beam-and-girder construction, and the laminated-floor-and-girder construction.

The term *mill construction*, formerly used to designate buildings of heavy timber construction, has come to have too broad a meaning to serve as a definition of a structural type. In some districts, industrial buildings of steel-frame construction are known as *mill buildings*. Accordingly, the National Fire Protection Association has adopted the term *slow-burning heavy timber construction* to include buildings of slow-burning heavy timber construction in which all walls are of masonry and in which the interior framing is of large timbers or in part of protected steel or reinforced concrete, and the plank floors and roof are arranged in heavy, solid masses and smooth, flat surfaces, avoiding thin or sharp projections and concealed or inaccessible spaces.

THREE TYPES OF HEAVY TIMBER CONSTRUCTION

Practice as developed in different parts of the country has led to three general classes of interior framing in the heavy timber type of commercial

[1] National Fire Protection Association, *Report* of Committee on Building Construction, Boston, Mass. 1928.

building, each commonly referred to by builders as *mill construction.* These classes have in common certain basic points and differ mainly in their details of floor construction. They may be divided into types, as follows:

1. Floors of heavy plank laid flat upon large timber girders which are spaced not less than 8 ft. on centers. These girders are supported by wood posts or columns at intervals of not less than 12 ft. This type is often referred to as *standard mill construction,* or the *girder type of heavy timber construction.*

2. Floors of heavy plank laid flat upon large timber beams which are spaced not less than 4 ft. on centers and supported by large timber girders spaced as far apart as the loading will allow. These girders are carried by wood posts, or columns, located as far apart as consistent with the general design of the building. This type is more generally known as *semi-mill construction* or the *beam-and-girder type of heavy timber construction.*

3. Floors of heavy plank laid on edge and supported by girders which are spaced not less than 12 ft. on centers. These girders are supported by wood posts, or columns, spaced preferably not less than 16 ft. apart. This type is called *laminated mill construction* or the *laminated type of heavy timber construction.*

Each of these types is provided with a lighter top floor, to take the wear and give a finished surface.

Some details of each type follow.

Girder-type or Standard Mill Construction.—The girder type of construction admits of a maximum column spacing in one direction of approximately 12 ft. While such spacing may not be objectionable in modern textile mills, nevertheless it has been shown by experience that areas where the columns are so closely spaced are not so readily leased as are those where the spacing is greater. Until quite recently the standard spacing of columns in buildings that were to be rented was 16 by 16 ft. Today, nearly without exception, the tenant requires more room, and bays 16 by 20 or 20 by 20 ft. are the rule, while floor areas that are broken up by many columns can be rented only by making concessions.

Typical details of this form of construction, where the flooring is laid flat, directly on the girders, without the use of floor beams, are shown in *Plates* 61 and 62.

Pintles.—The method of fastening beams to the walls, and to each other where they butt together, is of great importance in securing rigidity. These joints involve connections with the columns, and it is with respect to such details, and to connecting the beams together, that architects unversed in this type of construction are likely to have difficulty. Columns should rest end to end upon each other from top to bottom of buildings, but it is better that the columns themselves should not pass

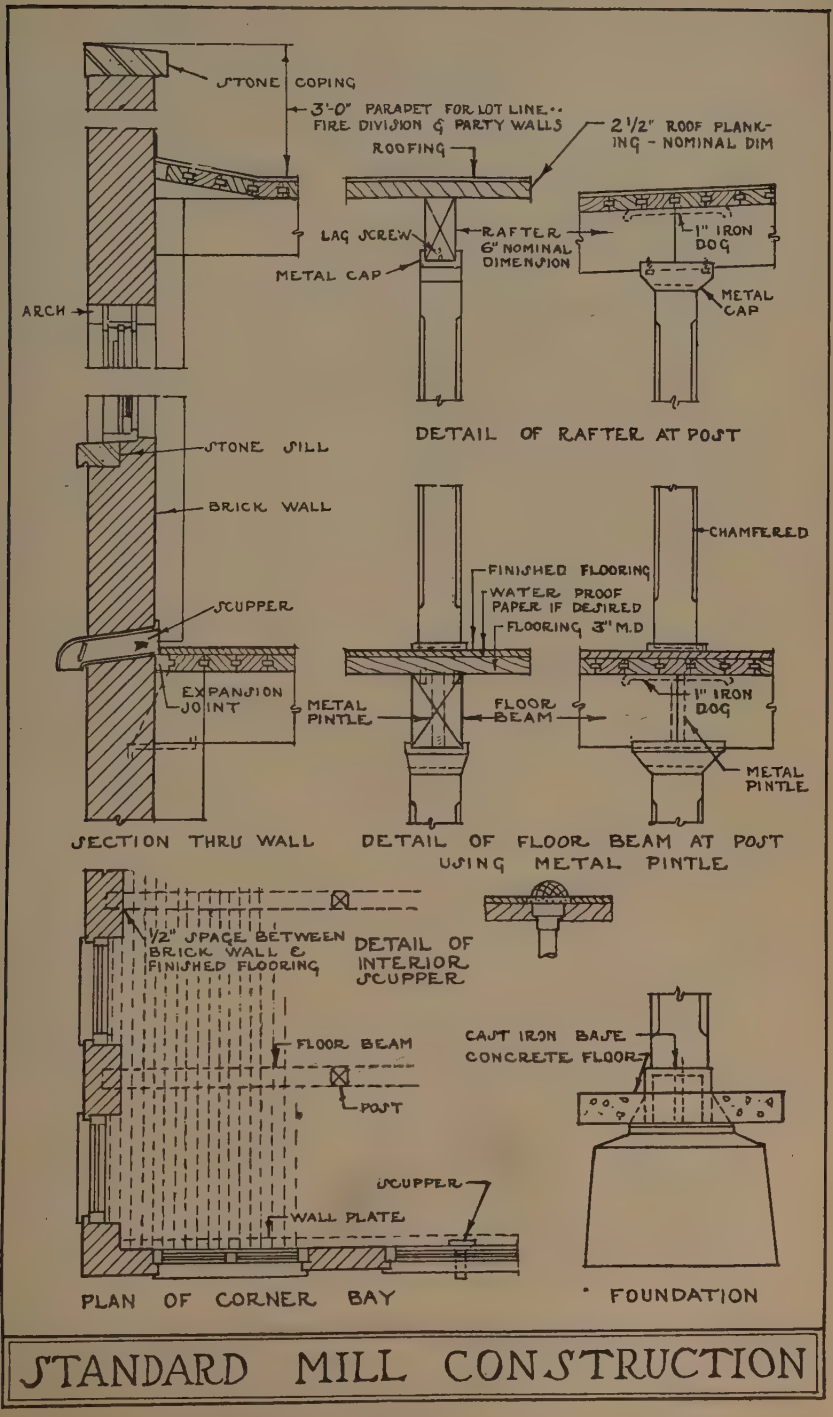

STONE COPING
3'-0" PARAPET FOR LOT LINE.. FIRE DIVISION & PARTY WALLS
ROOFING
2 1/2" ROOF PLANKING - NOMINAL DIM
LAG SCREW
RAFTER 6" NOMINAL DIMENSION
1" IRON DOG
METAL CAP
ARCH
METAL CAP
DETAIL OF RAFTER AT POST
STONE SILL
BRICK WALL
SCUPPER
EXPANSION JOINT
METAL PINTLE
FINISHED FLOORING
WATER PROOF PAPER IF DESIRED
FLOORING 3" M.D
FLOOR BEAM
CHAMFERED
1" IRON DOG
METAL PINTLE
SECTION THRU WALL
DETAIL OF FLOOR BEAM AT POST USING METAL PINTLE
1/2" SPACE BETWEEN BRICK WALL & FINISHED FLOORING
DETAIL OF INTERIOR SCUPPER
FLOOR BEAM
POST
SCUPPER
WALL PLATE
PLAN OF CORNER BAY
CAST IRON BASE
CONCRETE FLOOR
FOUNDATION
STANDARD MILL CONSTRUCTION

Plate 61.

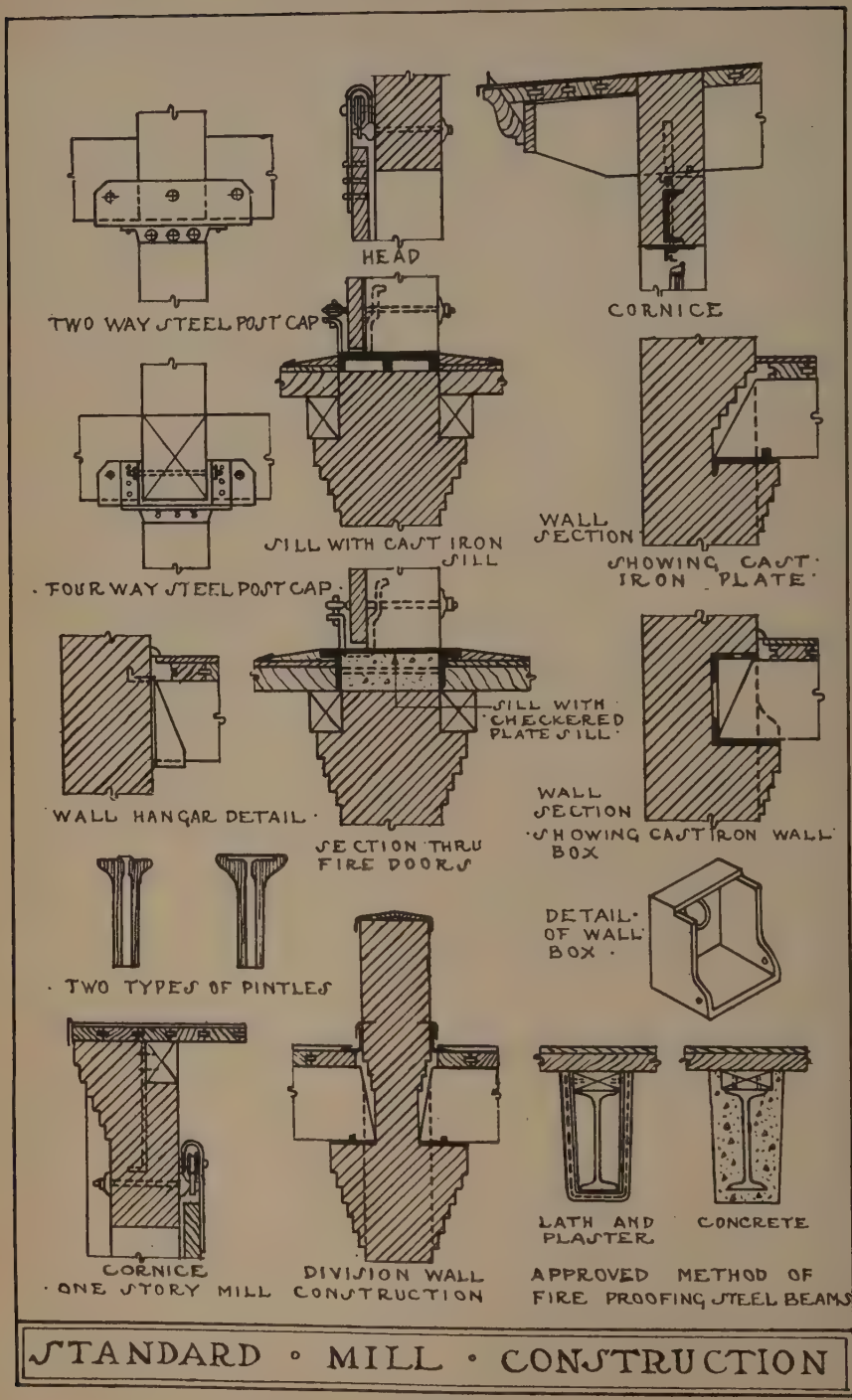

HEAD
TWO WAY STEEL POST CAP
CORNICE
SILL WITH CAST IRON SILL
WALL SECTION SHOWING CAST IRON PLATE
FOUR WAY STEEL POST CAP
SILL WITH CHECKERED PLATE SILL
WALL HANGAR DETAIL
WALL SECTION SHOWING CAST IRON WALL BOX
SECTION THRU FIRE DOORS
DETAIL OF WALL BOX
TWO TYPES OF PINTLES
CORNICE ONE STORY MILL CONSTRUCTION
DIVISION WALL CONSTRUCTION
LATH AND PLASTER
CONCRETE
APPROVED METHOD OF FIRE PROOFING STEEL BEAMS
STANDARD • MILL • CONSTRUCTION

Plate 62.

through the floors and between the ends of the beams, as they do where post caps are used without pintles. Another objection to the use of post caps is that the floor beams rest on steel angles, lag screwed to the post for support. The posts should stop at the bottoms of the beams and begin again at the tops. Between the top of a column and the bottom of the one above it, there should be a short, separate, cast-iron column known as a *pintle*. Being made of cast iron, which is a material of great compressive strength, it may be relatively small in diameter and requires only a small hole through the beams to accommodate it, half of the hole being in the end of one beam and half in the other. The lower end of the pintle rests on the cap of the lower column, and the top of the pintle receives the lower end of the column above.

There are several advantages in this construction. In the first place, the beams actually butt against each other, and having only a small hole through them (not much over 4 in. in diameter), the ends of the beams are actually over the body of the column and are not supported entirely by the overhanging ends of the column cap. If a cap end is burnt off, or breaks off, the beam is held as securely as ever.

The pintle construction, as noted above, permits the beams to butt against each other and thus become perfect struts to transmit pressure from one side of the building to the other; it also gives room to put two iron dogs, or ties, in the tops of the beams, one on each side of the pintle, to tie the beams together. Thus, the beams become not only struts but also rigid and continuous ties, to keep the sides of the building in their proper relative positions. At the same time, the pintles and dogs fulfil the necessary conditions before mentioned of being surrounded by heavy wood, for the pintles are within the beams, and the dogs are embedded in grooves in the tops of the beams and covered by floor planks. Flames around the top of a post might otherwise easily weaken the beam support and cause a collapse long before the strength of the framework was seriously affected. The dogs cannot work out, moreover, because they are beneath the planks.

Where the pintles enlarge at the top to take the upper column base, their top edges may be slightly exposed to fire but injury is not likely to result. When the beams and planks shrink, the pintle tops become more exposed than at first; allowance should be made for this. It should be observed, also, that the enlarged hole for the top of the pintle is in the plank and not in the beam, where it might weaken the framework.

Two types of pintles are shown in *Plate* 62. The one at the left is the type preferred for timber columns, and the type at the right for steel or cast-iron columns. A recessed bearing should not be used for timber columns, as the pocket will hold moisture and thus cause rotting of the wood.

Beam-and-girder Type or Semi-mill Construction.—The beam-and-girder type of construction differs from the girder type in that it has floor beams between the girders, to support the floor. These beams may rest on girders or be framed into their sides by metal hangers.

Plate 63 shows typical post, girder, and beam connections, where the beams rest directly on the girders. From a purely structural standpoint, this is the best method. Where intermediate beams are to be used, the space over the girders affords room for shafts or upper strands of belting.

Plate 64 shows semi-mill construction where the tops of the floor beams are nearly level with the tops of the girders and are supported by metal stirrups, or beam hangers. This method cuts down cost by decreasing the wall height for each story. It also eliminates air spaces between the girders and the flooring above them. The beams should always be set at least 1 in. above the girder to prevent bulging of the floor above from shrinkage of the joists.

This type of construction is not, however, looked upon with favor by insurance underwriters. They claim that experience has shown that such stirrups or hangers are likely to prove hazardous during exposure to fire, either causing the heavy timbers to burn off more quickly at the point of suspension in the stirrup or hanger or allowing the beams to fall due to failure of the metal stirrup or hanger.

Following is a comment upon this point from a handbook on fire protection:

> Mill construction, particularly in the Middle West, has suffered unfairly in reputation by reason of disastrous fire results, because buildings somewhat resembling this type have borne its name. They may have had floors and roofs of plank or wide spaced timbers, but in other particulars violated the principles of "mill construction." A common defect has been the use of exposed steel or iron stirrups to hold important floor timbers.

Laminated-floor Construction.—Heavy timber construction with laminated floors is a development of the girder-type or "standard mill construction" to meet heavier modern loadings. Here, the flooring consists of thick planks laid on edge and placed tightly together.

Some objections have been made to this method because of the liability to dry rot, but the use of dry lumber prevents rot. An ingenious plan that has been tried is to use lumber dressed only on the edges, so that the roughness of the sides of adjoining planks will prevent them from fitting tightly and will provide air space between for ventilation. The plan is said to be highly successful.

Details of this type, illustrated in *Plate* 65, do not differ essentially from those in standard mill construction shown in *Plates* 61 and 62.

The laminated flooring consists of planks, 6- to 8-in. wide and 2- or 3-in. thick, surfaced either on all sides or on one side and one edge, set

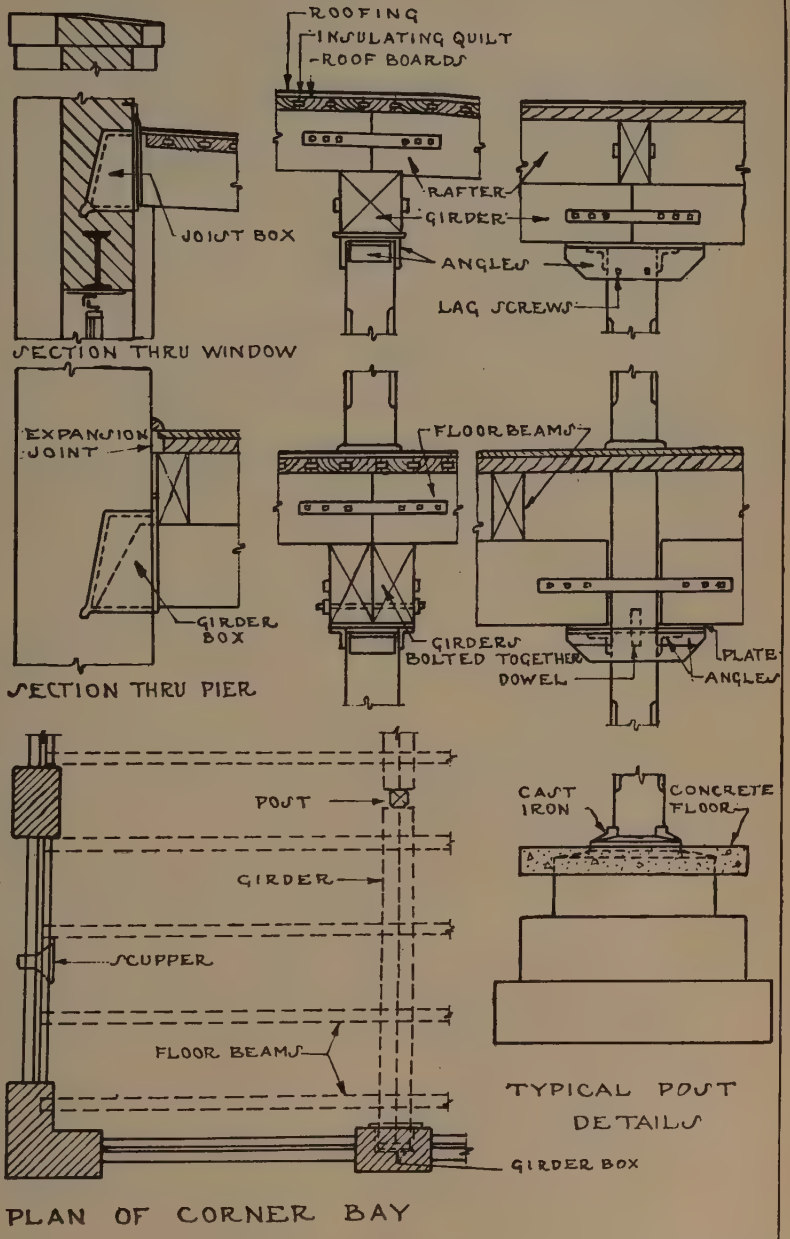

ROOFING
INSULATING QUILT
ROOF BOARDS
RAFTER
GIRDER
ANGLES
LAG SCREWS
JOIST BOX
SECTION THRU WINDOW
EXPANSION JOINT
GIRDER BOX
SECTION THRU PIER
FLOOR BEAMS
GIRDERS BOLTED TOGETHER
DOWEL
PLATE
ANGLES
POST
GIRDER
SCUPPER
FLOOR BEAMS
GIRDER BOX
PLAN OF CORNER BAY
CAST IRON
CONCRETE FLOOR
TYPICAL POST DETAILS
SEMI-MILL CONSTRUCTION
WITHOUT STIRRUPS

Plate 63.

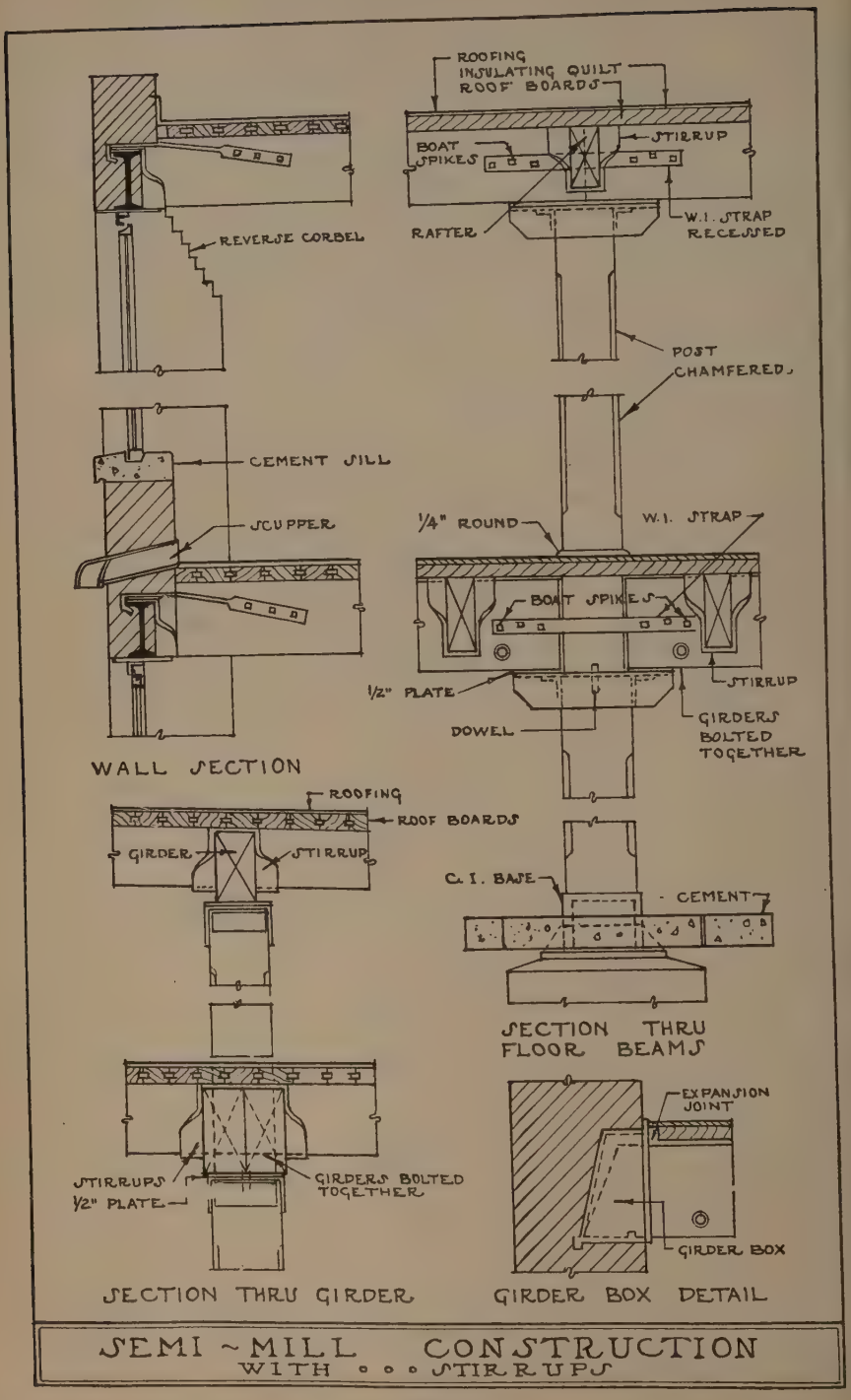
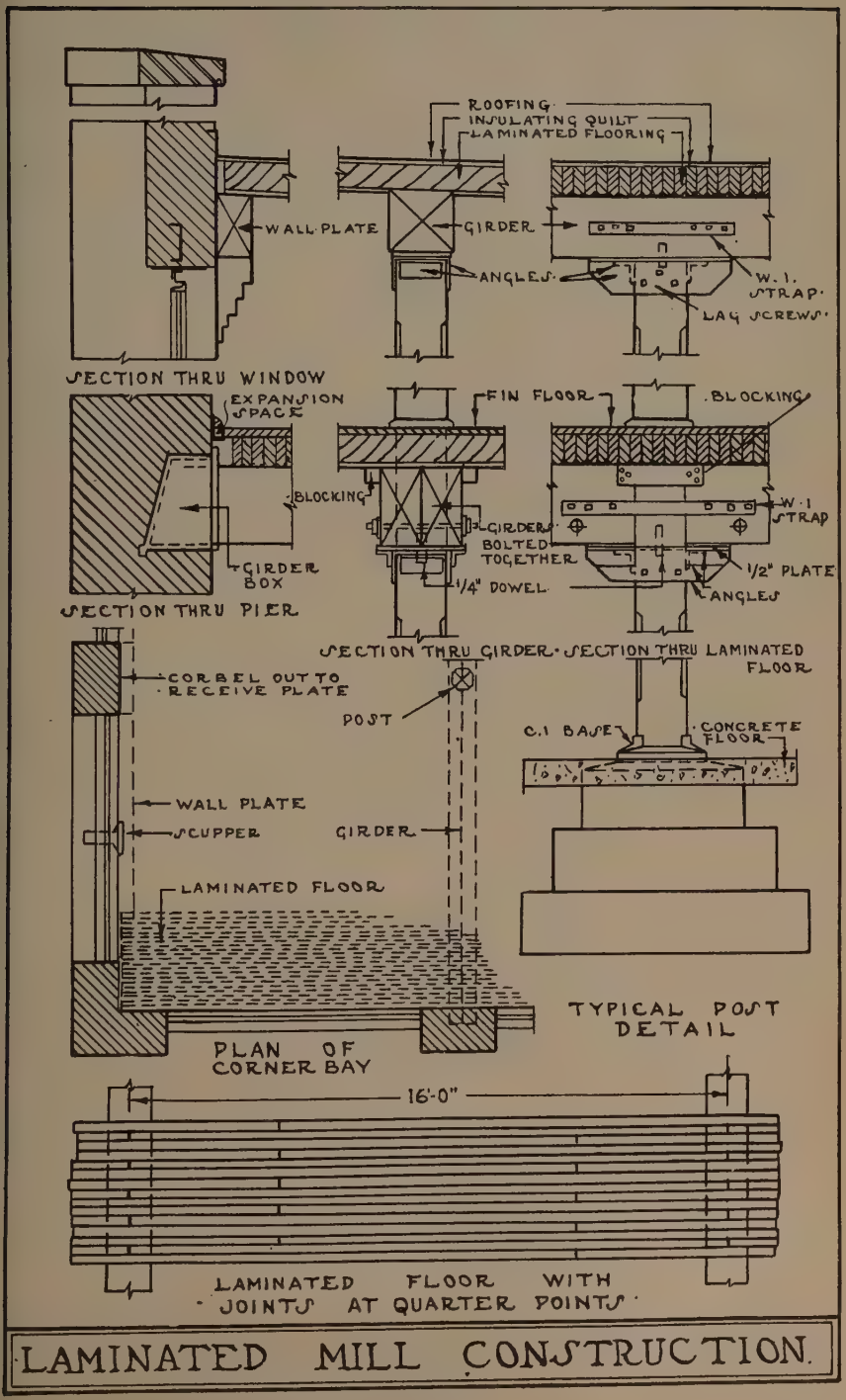

REVERSE CORBEL
ROOFING
INSULATING QUILT
ROOF BOARDS
BOAT SPIKES
STIRRUP
RAFTER
W.I. STRAP RECESSED
POST CHAMFERED
CEMENT SILL
SCUPPER
1/4" ROUND
W.I. STRAP
BOAT SPIKES
1/2" PLATE
STIRRUP
DOWEL
GIRDERS BOLTED TOGETHER
WALL SECTION
ROOFING
ROOF BOARDS
GIRDER
STIRRUP
C.I. BASE
CEMENT
SECTION THRU FLOOR BEAMS
STIRRUPS
1/2" PLATE
GIRDERS BOLTED TOGETHER
EXPANSION JOINT
GIRDER BOX
SECTION THRU GIRDER
GIRDER BOX DETAIL
SEMI ~ MILL CONSTRUCTION
WITH ... STIRRUPS

Plate 64.



LAMINATED MILL CONSTRUCTION.

Plate 65.

closely together on edge, firmly nailed at each end and at about 18-in. intervals, with 60-d. nails alternating top and bottom. The lower edges of the plank may be beveled to serve as a finish on the ceiling below.

Where plank floors are laid flat, the boards should be two bays in length if possible and laid to break joints every 4 ft. In the laminated type, it may be difficult to obtain plank two bays in length. A strong and stiff floor will result if the planks are laid with the ends extending between centers of girders with one plank laid across the girder at frequent intervals (every sixth or eighth piece) to act as a tie in the floor. Or, by another method, the ends of planks should join at or near the quarter point of the span between girders, taking care to break joints in such a way that no continuous line across the floor will occur. *Plate* 65 shows an example of this in which the span between girders is 16 ft. and the planks are 16 ft. long. The method of lamination shown is as follows:-

Every third piece of plank extends from center of girder to center of next girder. Next to this piece of plank, a second piece of the same length is nailed with the end spaced at a quarter point of the span between girders, thus allowing one end of the length to project three-fourths of the way across one span and one-fourth of the way across the other. The next piece of plank is placed over the opposite girder in the same manner that the previous is placed over the first girder. The lamination is completed by placing a length of plank from center of girder to center of girder as in the first case. Care is taken to see that each plank is nailed firmly in place with a tight joint between each two pieces of the floor.

In laying laminated floors, it is advisable to omit the last two planks at walls until after glazing and roofing have been completed. Then these spaces should be filled in, leaving ½ in. or so as clearance to provide for expansion of the flooring. It is often recommended that laminated floors be laid without nailing to the girders which support the floor, so that expansion in the floor due to dampness will not cause movement in the girders at the walls.

FACTORS AFFECTING DESIGN

One of the distinctive purposes of slow-burning heavy timber construction is to obtain strength and stiffness with a minimum amount of timber surface and a minimum number of corners exposed to attack by fire. Large supporting members and flat, smooth, heavy floors accomplish this purpose. Large timbers do not ignite readily and, if exposed to fire, burn slowly and with but slight penetration, even after a considerable period of time. Flat, smooth surfaces possess this same resistance to combustion and may be reached easily by water from sprinklers or hose. The factor of safety used in calculations for size of girders, beams, and columns is ample to allow serious charring by fire and still leave strength

sufficient to support the floor loads. Wood posts have successfully withstood fires that would have entirely crumpled unprotected cast-iron or steel columns.

The design of the three types of heavy-timber construction, *standard*, *semi-mill*, and *laminated floor*, is based upon these significant facts. In mill-construction types, heavy timber posts support large timber girders placed as far apart as the design will allow. These girders support a thick main or carrying floor direct, without aid of joists or smaller timbers, except in semi-mill construction.

The general design of the building, the floor loads, economy and arrangement of pipes for sprinkler system, and economy in the use of lumber are all factors affecting the size of bay. Economical use of lumber is insured by the choice of such a span that the full working strength of a given commercial size of material may be utilized in standard lengths, without giving excessive deflection. In standard mill construction the width of bay will ordinarily vary from 8 to 11 ft. on centers, while with laminated floors, the bay will vary from 12 to 18 ft. in width.

Narrow bay construction (4 to 5 ft. center to center of timbers) is not true mill construction and is undesirable for several reasons. There are more corners, angles, and surfaces on which fire may feed and spread. Timbers are smaller and are more quickly burned through. Water from sprinklers or hose streams cannot be used to the best advantage. Owing to the expense, and also because of the great number of sprinklers in the same fire area, it is not always feasible to place a line of sprinklers in every bay, and if this is not done the sprinkler protection is not satisfactory.

The heights of different stories of a building should be controlled by the character of occupancy or by special processes necessary in the manufacturing industry.

Building ordinances and insurance codes or specifications have established certain minimum sizes of girders and posts and minimum thickness of floor plank. This action tends to preserve the distinctive points of mill construction and distinguish it from ordinary light framing. While all ordinances and codes do not agree in detail, the same purpose is indicated in each.

Girders or beams are commonly required to be at least 6 in. in either dimension; often a cross-sectional area of 72 sq. in. is also demanded. Some cities require 8 in. as a minimum dimension. All timbers are to be planed on all sides.

Factors of weight, deflection, vibration, and impact should be considered in figuring the dimensions of beams or girders to be used in any given case.

Girders are preferably a single stick, but for sizes above 14 by 16 in. it is often advantageous to use two pieces 8 by 16 in., or a similar combination, bolted together securely side by side with the larger dimension

vertical. It has been the custom to leave an air space about ¾ in. wide between the two members thus fastened, the idea being that the air spaces facilitate drying and thereby prevent the rotting of the timber. It more frequently happens, however, that such air spaces provide a culture chamber for fungus and also encourage the progress of a fire where it is impossible to get at it, either with sprinkler system or stream from a hose, and where the entire frame of the building is quickly weakened. When it is impossible to get beams sufficiently large in a single section to carry the girder loads, it is generally considered better practice to bolt them solidly together than to leave a small air space.

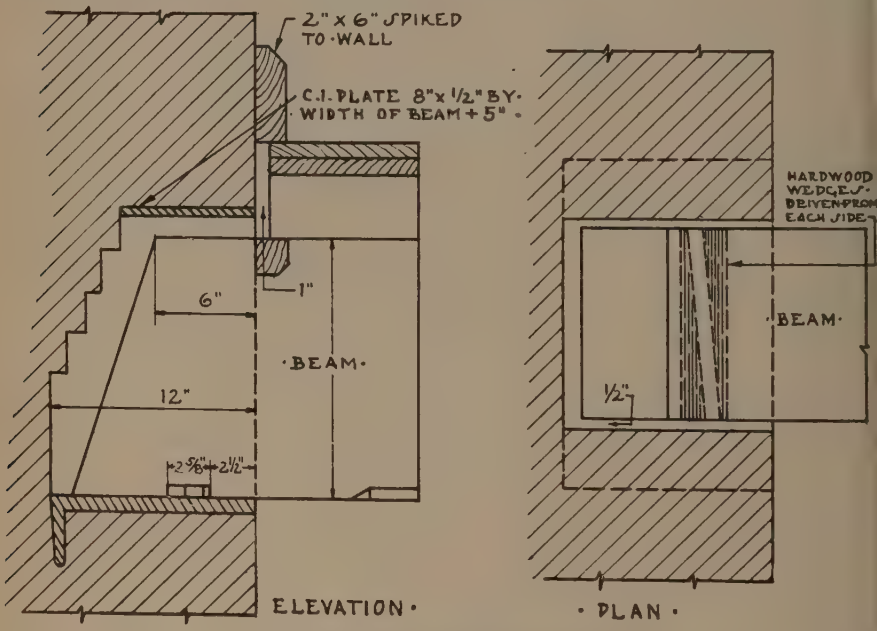


FIG. 104.—Detail of wall bearing.

Bolts ¾ in. in diameter, fitted with nuts and 3-in. washers, are often used to fasten double girders. The extreme bolts are placed about 2 ft in from the end, while the others are staggered at equal spacing along the length. The spacing longitudinally should not be greater than four times the depth of the girder. Contact surfaces should be treated with a preservative to prevent decay.

Where girders meet at the column they should be fitted around the column or butted up close to it. Ends of girders may be drawn together closely by dogs driven into the top, or held in place by steel or iron straps spiked, bolted, or secured by lag screws.

The length of the bearing at the end of the girders should be such that the bearing area will be sufficient to allow a suitable unit stress in compres

sion across the grain of the wood. A minimum length of 5 in. is often required, but an exact determination should be made after the width of the girder is known. When girders rest on metal plates or masonry, they should have the bearing surfaces protected by a piece of creosote-saturated felt or paper, or two brush coats of hot creosote.

Girders are supported at the wall by metal wall plates or wall boxes built into the wall as shown in Fig. 104, thus distributing the loads more evenly on the brickwork. Wall plates should have two flanges—one to anchor the plate to the wall, and the other to hold the girder on the plate. Care should be taken to see that a ½-in. air space is left around the ends of girders for ventilation, so as to prevent decay. A preservative treatment applied to wall ends of the girders will give added security. It is advisable to allow end play in girders, to prevent strains in the walls. Ends of girders should be cut at such an angle that, in case of damage by fire, the member may tip out of the wall opening without disturbing the wall.

Arrangement of Beams.—Instead of having the intermediate beams supported by I beams running between the pilasters (see wall section, *Plate* 64), the I beam may be used only as a support for the brick curtain walls and window sashes; the beams in that case would be supported by a girder running parallel to the I beam and having its ends secured in the pilasters. In this event the strap anchor may be omitted, the beams being supported entirely by the stirrups. This method of framing the beams in the side walls provides a wall construction which is thoroughly independent of the floor construction, so that any failure of the latter would not affect the stability of the wall.

Floors.—The main or carrying floor should be at least 3 in. thick if laid flat upon the beams or girders. The top or wearing floor may be of 1-in. material. These sizes are nominal and not actual.

Floors of slow-burning construction are ordinarily of one of two types. In one, commonly called *mill floor*, planks of either dressed and matched or splined material, surfaced both sides, are nailed direct to the supporting members. Material 4 in. or more in thickness should have the edges grooved to take a ¾- by 1½-in. spline. The other type, known as *laminated floor*, has already been discussed.

The top floor may be of softwood or hardwood as use demands. Tongued-and-grooved flooring is used almost entirely. Square-edged flooring is easier to replace when repairs are needed but wears less around the face nailing than at other points, thus making an uneven floor. Some of the best buildings have a double top floor, the lower part of softwood laid diagonally upon the plank underfloor, and the hardwood upper part laid lengthwise. This latter method allows boards in alleys or passages to be easily replaced when worn, especially where the top floor is laid, as it should be, so that the length of the pieces is parallel to the direction

of the traffic. Usually, this is lengthwise of the building. The diagonal boards brace the floors, reduce vibration, and distribute the floor load evenly. End-matched flooring is economical and can be used to advantage here.

Two thicknesses of saturated-asphalt felt or a two-ply layer of the same material is frequently used between bearing and surface floors. Care must be taken to have both floors throughly dry or the retained moisture will cause dry rot. Reasonable tightness of floors can be assured by the use of thoroughly dried lumber tightly driven up, because of the side matching or splines. In case sprinklers are opened by fire, the swelling of such dry floor planking precludes serious leakage.

The corbeling of the brickwork about the edges, to make a tight joint between the wall and floor, prevents the shrinkage of the plank floor from

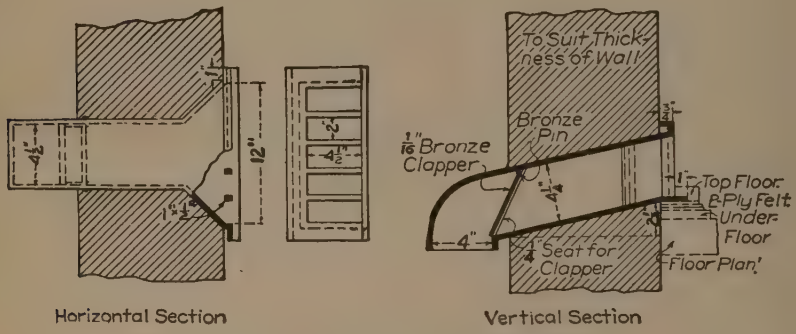


Fig. 105.—Scupper for drainage of floors.

leaving a wide crack next to the wall, through which fire can quickly travel from floor to floor. Drafts can cause the ends of supporting timbers to burn off rapidly. This point is emphasized because the tightness of this joint is of more importance than the support it affords to the floor planks; its fire resistance depends on absence of cracks in the joint. It should be noted that clearance has been allowed next to the wall, as shown in Fig. 104; this provides for any swelling of the floor.

Where extra precaution is desired to prevent leakage of water through floors, the various layers of waterproof paper should be laid to break joints, and each joint mopped with hot tar or a similar protective material. Also, floors may be given a pitch of 1 in. in 20 ft., and scuppers similar to that shown in Fig. 105 installed at floor level. These should be spaced according to the recommendations of the local fire insurance rating bureau.

Scuppers and waterproof floors are required only in warehouses and where high-valued stock, particularly susceptible to water damage, is located on the floors below, or where flash fires are particularly prevalent.

Where scuppers are used they should be placed over windows in order not to decrease the effective area of the piers.

A detail of an interior floor drain is also shown in *Plate* 61. Such drains are sometimes used instead of a scupper. They have certain advantages and are an acceptable alternative. Where in the open they should be flush with the floor.

The use of an approved elastic felt instead of waterproof paper is sometimes preferred, as nail holes through the paper may permit leakage. Experience shows that felt properly laid gives better satisfaction in the long run. When special waterproofing of a floor is required it is recommended that a rough board floor be laid on top of the heavy plank floor and that the waterproof felt be placed on this rough floor. A fairly smooth surface must be provided before the felt is laid, and any irregularity in the floor more than $\frac{1}{8}$ in. deep should be filled up. Two layers of felt are used, breaking joints and mopped with a sealing compound between the plies and on top of the felt. It is recommended that the felt be turned up 6 in. at the posts and at the side walls. The hardwood top floor is laid in the hot compound closely following the final mopping, so that the nails holding it down are tightly gripped.

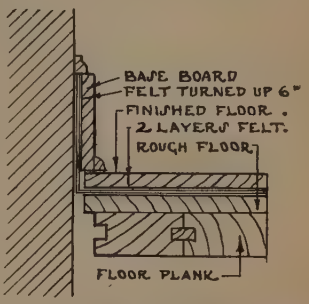


FIG. 106.—Section of mill floor and side-wall flashing.

At the walls the felt is protected by a counterflashing of galvanized iron or copper or by a baseboard nailed in place with the joints between it and the floor covered by a quarter round. Both the baseboard and quarter round should be kept free from the top floor to allow the latter to move without breaking the corner of the turned-up felt. At the columns the felt may be protected by a baseboard and quarter round, as at the walls. Figure 106 gives details of floor construction and flashing at side walls, as described.

Roofs and Roof Coverings.—Roofs in heavy-timber buildings are usually flat, with a slight pitch of $\frac{1}{4}$ to $\frac{3}{4}$ in. to the foot. They are framed in the same manner as are the floors, the underside of the roof forming the ceiling for the top story. If a plastered ceiling is necessary, as in the case of an office, the metal lath which is to hold the plaster should be fitted around the girders and beams and against the roof boards in such a manner as to leave no spaces between the plaster and wood. If plastering is to be used in contact with the timber, it should be of plain lime mortar without hard finish. The rough plaster is sufficiently porous to permit seasoning to continue if necessary.

Both roof timbers and planks should be self-releasing at walls and should have exposed surfaces dressed.

Roofs should be covered with an incombustible material. Metal, tile, asbestos, or a combination of coal tar, pitch, or asphalt and felt covered with slag or gravel may be safely used. Slag or gravel built-up roofing is probably more used than the other types.

The size of the girders to support the roof need not be so large as those used for supporting the floors, on account of the lighter load carried, but the minimum sizes of materials permitted by ordinances, laws, or rules will control the size of girders. From the standpoint of fire protection, the smallest roof beams or girders that should be used are at least 6 by 10 in. (nominal) in either dimension.

In many cases, a roof of the semi-mill-construction type is placed on a building in which all the floors are of standard mill construction or of the laminated type. This design is not necessary, since a certain minimum thickness of roof plank is demanded regardless of the load to be carried. While 2½ in. (nominal) for minimum thickness is allowable, 3 in. (nominal) is the more common requirement. This is sufficient to support ordinary roof loads on spans commonly found between girders. Roof planks 2 or 3 in. in thickness may be either splined or tongued and grooved; with a thickness of 4 in. or more, they should be splined.

The choice of roof coverings depends on a number of factors and is partly determined by the pitch or slope of the roof. It is usually recognized that prepared or ready roofing cannot be used on pitches less than 1 in. in 12 in., while built-up slag or gravel roofing may be used on roofs with the minimum pitch of ¼ in. in 12 in. Some manufacturers are now recommending a dead-level roof. This is particularly desirable when added stories are contemplated.

One of the most satisfactory types of roofing is of the built-up variety, where layers of felt saturated with tar are nailed down, and, by the use of asphalt or pitch, protected and cemented together. The following specification gives what is considered to be good practice in the construction of a flat built-up roofing on wood sheathing:

Specification for Felt, Pitch-and-gravel, or Slag Roofing over Boards. *Incline.*—This specification should not be used where roof incline exceeds 3 in. to 1 ft. Modern practice tends to reduce this slope to 2 in. to 1 ft. For steeper inclines modified specifications are required.

Roofing:

1. Lay one thickness of sheathing paper or unsaturated felt weighing not less than 5 lb. per 100 sq. ft., lapping the sheets at least 1 in.

2. Lay two plies of tarred felt weighing 14 to 16 lb. per 100 sq. ft., lapping each sheet 17 in. over the preceding one, and nail as often as is necessary to hold in place until remaining felt is laid.

3. Coat the entire surface uniformly with straight-run coal-tar pitch.

4. Lay three plies of tarred felt, lapping each sheet 22 in. over the preceding one, rolling each layer into hot pitch so that in no place shall felt touch felt. Such

nailing as necessary shall be done so that all nails will be covered by not less than two plies of felt.

5. Spread over the entire surface a uniform coating of pitch, into which, while hot, imbed not less than 400 lb. of gravel or 300 lb. of slag to each 100 sq. ft. The gravel, or slag, shall be from ¼ in. to ⅝ in. in size, dry, and free from dirt and sand.

Flashings shall be constructed as shown in detailed drawings.

All felt and pitch shall bear the manufacturer's label. The roof may be inspected before the gravel or slag is applied by cutting a slit not less than 3 ft. long at right angles to the way the felt is laid.

NOTE.—To comply with the above specifications, the material necessary for each 100 sq. ft. of roof is approximately as follows: 100 sq. ft. sheathing paper, 80 to 90 lb. tarred felt, 150 to 160 lb. straight-run coal-tar pitch, 400 lb. gravel, or 300 lb. slag.

In estimating felt, the average weight is practically 15 lb. per 100 sq. ft., and about 10 per cent extra is required for laps.

In estimating pitch, the weather conditions and expertness of the workmen will affect the amount necessary for the moppings and to bed gravel or slag properly.

The sheathing paper or unsaturated felt is placed on the bottom next to the roof boards, mainly to keep any pitch which might penetrate the two-ply felt above it from cementing the roofing to the sheathing. It also is of value in preventing the drying out of the roof through open joints from below. The saturated felts should be nailed, where there is any chance of their being disturbed from below by the wind, and be nailed enough to stay in place while laying. The practice in regard to nailing varies in different parts of the country, but the fewer nails the better, as long as the roof is held in place.

Thorough inspection of materials and workmanship is recommended.

Cornices, Gutters, and Downspouts.—The necessity for a cornice is questionable, even from an architectural standpoint. It is a constant source of expense for maintenance and is likely sooner or later to become dangerous and to fall without warning, because of the failure of concealed members. Provided that a cornice is to be used, the open wood type shown in Fig. 107 is recommended. When there is exposure from neighboring buildings, an incombustible cornice is advisable. A far better treatment from a fire-hazard standpoint and one required in most cities is a parapet wall extending at least 3 ft. above the roof and coped either with a plain or an ornamental coping. In areas subject to high winds, a parapet wall, if used, should be as low as possible.

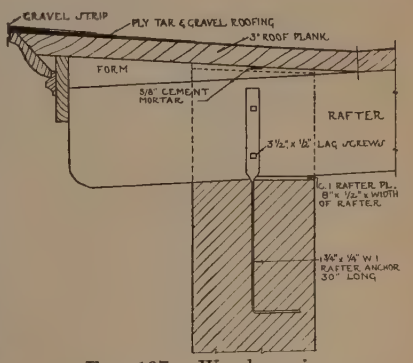

GRAVEL STRIP
PLY TAR & GRAVEL ROOFING
3" ROOF PLANK
FORM
5/8" CEMENT MORTAR
RAFTER
3½" x ½" LAG SCREWS
L. I. RAFTER PL., 8" x ½" x WIDTH OF RAFTER
¾" x ¼" W. I. RAFTER ANCHOR 30" LONG

FIG. 107.—Wood cornice.

Gutters should have a pitch of not less than 1 in. in 15 ft. Downspouts should be provided and are ordinarily proportioned 1 sq. in. of

pipe for every 100 sq. ft. of roof. Where the rainfall is excessive, this should be increased 25 per cent. Four inches in diameter is the minimum-sized downspout which should be used.

Trussed Roofs.—It was noted in a previous paragraph that in many types of commercial buildings, open floor spaces without posts are desired. This condition is likely to exist in manufacturing plants where large areas of clear floor are necessary for the movement of machinery or assembling machine parts. In such buildings, posts are eliminated and roof trusses used to span the opening. Trusses are ordinarily placed from 8 to 20 ft. on centers, with 3-in. plank spanning the distance between the trusses, as in standard mill roofs, or resting on purlins spaced not less than 8 ft. on centers and running from truss to truss. It is advisable to have the purlins supported at the joints of the trusses, to prevent bending in the members of the top chord. Other details of the roof are similar to those already described.

Saw-tooth Construction.—In one-story plants of large area, or in the top floor of many heavy-timber buildings, it is often desirable to secure

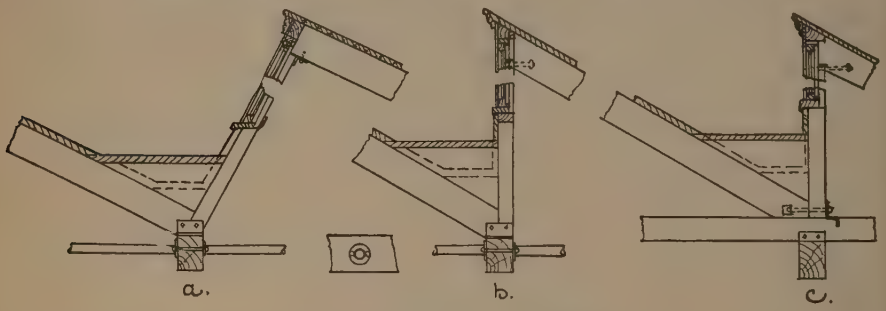


FIG. 108.—Saw-tooth roof details.

additional light as well as large areas of unobstructed floor space. This can be done by using the saw-tooth form of roof. The advantages of the saw-tooth roof construction are (*a*) excellent light, (*b*) uniform diffusion, permitting low headroom as compared with that required in ordinary monitor construction, and (*c*) increased efficiency, which cuts the cost of artificial lighting. The roof planks are supported by heavy timber beams or by steel trusses spaced from 8 to 10 ft. on centers and, in turn, carried by timber girders, trusses, or columns.

Windows in saw-tooth roofs should face the north or as nearly that direction as is possible. Faces containing these windows may be either vertical or inclined. Vertical faces permit the use of either sliding or hinged sash. Inclined faces give more uniform light, take advantage of the brighter light from the upper sky, and avoid the cut-off from adjoining saw-tooth sections; but they require a fixed sash, and horizontal muntins must be eliminated, as the water caught by them would gradually leak through to the inside.

Gutters must be constructed to carry the roof water to the downspouts. They are formed by the valleys and should have a minimum pitch of ½ in. per lineal foot. This will keep them free from silt and dirt. The height of sill line above the gutter is dependent on climatic conditions. The location of the downspouts will depend on the width of the building. In constructing the gutters, care must be taken to avoid forming concealed air spaces. Inside drip pans should be provided at the bottom of the windows to catch the condensation on the glass. These drip pans should be drained by inside conductors.

Figure 108, shows details of saw-tooth roof construction. Figure *c* shows details of a saw-tooth construction of which it was said by the architect:

> To avoid metal beam-hangers the longitudinal beams rest on top of the transverse beams and may be secured to them as shown or by spikes or other means which may occur to the designer. He should have in mind that what metal he uses should be buried in wood if possible, and if not, it should be above the beams. Resting the saw-tooth beams on top of the main transverse members, which secured the maximum fire resistance, causes the valleys to be narrower than most designers like, but by planking over high enough, sufficient width can be obtained.

In these details the roof planks forming the bottom of the gutter are supported by a built-up solid wood member as wide as the roof beam. This eliminates unnecessary corners and edges, thus cutting down the fire hazard.

Durability of Roofs.—Where a high humidity is to be maintained such as is usual in weave rooms, dye houses, pulp mills, and paper mills, special attention must be given to the design of the roof to avoid decay. With warm, moist air on the interior, and cold air on the exterior, a condition favorable to the growth of fungi is likely to occur in either the roof beams or the planking.

To prevent such humidity conditions from occurring within the beams or girders, chamfering their upper corners leaving only the minimum bearing area required for the roof planks, is recommended. If a width of bearing equal to the thickness of the roof plank is allowed, it will usually be sufficient.

The relative humidity of the air directly under the roof should be reduced by placing additional heating pipes there or by cutting down the escape of heat through the roof. If additional pipes are provided, they should be so placed that the heat is distributed as evenly as possible under the surface of the roof. In saw-tooth construction this is accomplished by placing them at the lower end of the incline of the saw tooth. Flat portions of a roof should be protected with more care because snow and ice remain for a longer period than on the more inclined portions and keep the roof chilled for a correspondingly longer time, thus causing greater

condensation. The remedy is to provide additional heating pipes under the flatter portions.

A good roof for buildings where a relatively high humidity is maintained consists of two thicknesses of plank, separated by an insulating material and covered by an approved roofing. The lower planks support the load and should be of a good grade of material. Over these are placed three thicknesses of tarred paper saturated with tar. The upper planks may be of a low-grade material and should be treated with a preservative. An approved roof covering is placed on top of the roof.

Relief from unusual moisture conditions may be realized in the use of roof planking, and also timbers, of the recognized highly durable species.

Roof ventilators, skylights, closet vents, and drains all cause condensation, and steps should be taken to avoid this precipitation of moisture. Wherever possible, roof ventilators in buildings of high humidity should be omitted, and drainpipes or vents should be insulated and kept away from structural members.

PRECAUTIONS AGAINST FIRE

Destruction by fire is not a transfer of values. It is absolute waste. In checking or reducing this waste, the sprinkler is one of the most important factors, if not the most important one.

Experience has proved, in very expensive lessons, the utter folly of depending upon incombustible materials alone for fire resistance in our buildings.

The science of fire protection is founded largely on experience, and experience has been a slow and expensive teacher. Data which would have proved to be valuable have sometimes been lost because of the confusion that usually exists at the time of a fire and the absence of trained observers. A careful analysis of an investigation in hundreds of fires, however, has enabled fire-prevention engineers to accumulate a fund of knowledge which could not possibly be acquired in any single experience.

Walls of stairs, elevators, and other shafts should meet the requirements of the fire tests for full protection, and when the walls of the shafts are self-supporting they should be built of brick laid in cement mortar, or of concrete, or of concrete block, plain concrete, or reinforced concrete. When reinforced concrete is used the minimum thickness should be not less than 6 in. When plain concrete or hard-burned brick or concrete brick is used, the minimum thickness should be not less than 8 in. When concrete blocks, clay tile, or gypsum tile is used, the minimum thickness should be not less than 12 in., but the local building code will usually govern this.

All such shafts should extend at least 6 in. above the roof level.

Elevator doors should be fire resistant and be provided with an interlocking device, so that the doors can be operated only when the car is at a

landing and the car cannot move until the door is closed. Lobbies leading to elevators should be separated from other parts of a building by a partition and by fire doors meeting the requirements of fire tests, for partial protection.

Stairways and Smokeproof Towers.—All stairs, landings, and openings thereto should have an unobstructed width throughout of at least 44 in., except that handrails may not project more than 3½ in. into such width on each side.

There should be not more than 12 ft. vertically between landings. All stair landings should be large enough to permit the openings of doors without interference with traffic within the enclosure. Suitable handrails or banister should be provided on each side of each flight of stairs. The treads and risers should be uniform throughout; and the treads should be constructed and maintained in a manner to prevent persons from slipping on them. No winders should be allowed.

All stairways should extend to the street level and open on the street or through an unobstructed passageway affording safe egress to the street. All exit stairs which extend to the top floor should continue to the roof.

Stairways which may be used as a means of exit should not extend continuously to floors below the street level, unless partitioned off in such a manner as will clearly indicate the street level, and the direction of egress to the street be plainly marked thereon.

Smokeproof towers should not communicate directly with the building on any floor. Entrance to these enclosures from floors above the street level should be either from external balconies or through vestibules entirely open through the outer air; and, from floors below the street level, through ventilated covered areaways or vestibules.

Balconies should be of substantial, incombustible construction, with solid floors properly drained. The sides of open-air stairs and balconies should be protected by suitable solid fireproof material, to a height of not less than 3 ft., 6 in.

One smokeproof tower may serve two buildings, if the size of the enclosure and the capacity of the stairway is adequate for the accommodation of the number of occupants in the two buildings.

Separation of Floors.—The horizontally divided building is designed to hold a fire from rising through the floors. Repeated experience has proved that excessively large and dangerous fires develop quickly, if floors are not fire-tight. Each floor should be absolutely cut off from every other floor, and each section from every other section, so that fires may not communicate.

Doors.—All exits should be provided with self-closing fire doors, arranged to open in the direction of traffic toward the outside of buildings. The doors should be so equipped that they can be operated in the direction of exit without the use of keys.

The doors of smokeproof towers should have a panel of wired glass, not more than one-third the area of the doorway. All exits should be properly and clearly marked both day and night. Elevator doors should be included.

Lighting.—All stairway enclosures, smokeproof towers, and passageways leading to the street should be lighted by either gas or electricity. If by electricity, the current should be obtained either from a source outside the building or directly by independent circuit taken from the main switchboard in the engine room.

Vents and Skylights.—A vent should be provided over each stairway or elevator shaft with a clear glass area equal to at least three-fourths of the horizontal area of the shaft; the vent should be provided with metal skylights or side windows; and the skylights should be protected above and below by heavy wire screens.

Vent shafts should be protected at the top by approved ventilating skylights or louvres.

All other openings in roof or roof structures should be provided with approved skylights, doors, or windows.

Rooms and Hall Partitions.—Partitions, if any, subdividing allowable areas, should meet the requirements of the National Fire Protection Association.

Doors and windows in such partitions should be incombustible.

Protection of Exterior Wall Openings.—All exterior windows should be protected by approved fire windows or such other protection as may be approved for the purpose.

All window openings exposed to buildings within 25 ft. should be protected by approved shutters or outside open sprinklers, in addition to the fire windows.

All exterior door openings should be protected by approved fire doors.

Protection of Interior Wall Openings.—All openings in fire walls should be equipped with approved automatic fire doors on each side of the wall.

If an opening in a fire wall is made to serve as an emergency exit, it should not exceed 48 sq. ft. in area, and a self-closing fire door should be substituted for one of the automatic fire doors.

Interior openings to ventilating shafts should be protected by approved automatic trap doors or shutters.

Openings in stair, elevator, and other shaft enclosures should be protected by approved self-closing fire doors.

All fire doors should be mounted with approved wrought-iron or steel hardware and be securely attached to the wall or partition or to approved frames anchored thereto.

Interior windows in stair or elevator shafts should be prohibited.

If chutes are provided, they should be protected in the same manner as elevator shafts.

Drainage.—Drainage outlets designed to permit inflow of air should be provided from all stories into shafts or drainage lines to carry off promptly three-fourths of the estimated volume of water from sprinklers or hose streams on any one floor. The lowest floor of the building should be drained to a sump chamber which is provided with adequate facilities for removing surplus water therefrom.

Service Equipment.—The room or rooms in which boilers and all power and operating machinery are located should be separated from other portions of the building by an 8-in. reinforced-concrete or 12-in. brick wall, having an automatic fire door at each opening, and such rooms should not have direct communication with the floor above.

All boilers should be separated from operating machinery by 8-in. walls, with approved fire doors at openings.

A standpipe should be installed at each stair tower.

The installation of the standpipe and hose should conform to the requirements of established standards.

Where any portion of the building on the grade floor, or any floor below the grade, is used for the storage or exhibition of merchandise, an approved automatic-sprinkler equipment should be provided in such portion.

All electrical equipment should be installed in accordance with the requirements of the National Electrical Code.

All heating, ventilating, and other service equipment should be separated from other portions of the building by enclosing walls meeting the requirements of fire tests for full protection for stairways and elevator enclosures; and all openings in same should be provided with approved fire doors.

Where the heating is by blower or indirect systems, the ducts should be substantially constructed and supported and should be insulated with a satisfactory, incombustible covering not less than ½-in. thick. The ducts should be provided with approved automatic cut-off devices.

Where gas is used for heating or lighting purposes, metal pipes with properly located valves should be used throughout. Any material of an inflammable nature should be protected from the flame or heat of the gas lighting, heating, or ventilating apparatus by metal and asbestos, or other fire-resistive, non-conducting materials. Where gas is used, approved outside cut-off devices should be provided. No swinging gas fixtures should be permitted.

Exterior Walls.—It has been pointed out that in slow-burning heavy-timber construction, buildings must be so constructed that fire will pass as slowly as possible from one part of the structure to another and, in addition, when located in the closely built districts of cities, must be fire

resistive to external conflagration. Careful attention must be given to the location and construction of external walls, the location and construction of fire walls, the enclosing of stairways, and the protection of openings in fire and enclosure walls, and, also, of openings in exterior walls exposed to external fire hazards, in order that the advantages of this type of construction may be secured. Wooden beams should not enter walls farther than is required for sufficient bearing, and, in all cases, there should be at least 8 in. of brick at the sides and ends of these beams.

City building ordinances, as well as the recommendations of the insurance underwriters generally, specify exterior walls of incombustible material, such as hard-burned brick or stone laid in cement mortar or concrete. The pilastered form of brick or reinforced-concrete wall gives large window areas and furnishes support to the main girders of the floors where needed. This general type of construction may be carried out either in the form of curtain walls or panel walls, at the choice of the designer. Panels of reinforced concrete have been used in a few recent cases. In this way, a fireproof lintel, which may be used with good architectural effect, may be secured.

Practically all large communities specify in their building ordinance the thickness of the walls for any given case. When excessively heavy loads are carried, it may be necessary to increase the thickness of these requirements for brick walls, in order that the allowable crushing strength of the masonry be not exceeded. It is well to remember that brick walls properly bonded and the joints flushed full with cement or cement-lime mortar are generally recognized as being as strong as poorer walls 4 in. thicker.

Heavy Timber Side Walls.—In small buildings or structures located well out of congested districts and separated from other buildings, exterior walls are occasionally made of heavy timber construction as in the case of floors. The posts which are to form the exterior framing should be of a size needed to carry the load from the floor above but should not be less than 10 by 10 in. These posts should be spaced from 8 to 10 ft. apart, as in the case of the floor girders, and should be thoroughly braced at the corners of the building and around openings to provide stiffness.

The walls may be of plank 2 in. or more in thickness. Tongued-and-grooved or splined material is placed vertically and nailed to horizontal girts extending between the posts. Square-edged plank may be used by covering the cracks with $\frac{1}{2}$-in. battens. If metal siding is to be used as an exterior finish, the planks should be placed horizontally and fastened to the posts. If necessary, intermediate studs should be provided. Planks nailed diagonally will aid in stiffening the building, but there is a small waste of material involved. All interior surfaces should be left exposed so that water may reach them easily in case of fire.

Floor Areas.—As a matter of economy, floor areas between fire or exterior walls should be as large as permitted, since the cost of fire walls and the necessary protection of openings add materially to the cost of the building. The maximum allowable floor areas between fire walls or exterior walls of slow-burning heavy-timber buildings, not over 75 ft. or six stories in height, are as follows for any one story:

	Without Sprinklers, Square Feet	With Sprinklers, Square Feet
Building fronting on one street.....	10,000	20,000
Building on two streets.....	12,000	24,000

It is further recommended that these areas may be increased for buildings three stories or less in height, if sprinklered and of non-hazardous occupancy.

Local building ordinances should be consulted in every case, as they may differ from the above allowable areas. Many examples may be found in the cotton and woolen mills of the New England states in which these areas have been exceeded, even in the practice of leading engineers and architects.

Automatic Sprinklers.—The history of the development of lumber-built industrial plants of the heavy girder type, commonly known as *slow-burning construction*, is closely interwoven with the development of the automatic sprinkler. The combination of slow-burning construction and automatic sprinklers gives a practically complete measure of fire resistance in the completed and occupied building.

The automatic sprinkler came into use during the last quarter of the last century, and the combination of slow-burning construction and sprinklers reduced industrial fire risks enormously. The average losses in the year 1870 were about 61.4 cts. per $100, a low rate for that time. The average loss by fire from 1914 to 1924 was only 4.4 cts. per $100 of insurance, and the cost of insurance only 8.5 cts. as against 36.3 cts. per $100 50 years ago.

Fire control is very desirable in any construction, in order to protect stock and, finally, the building itself.

Two phases of fire control should be considered: the active phase, which consists of extinguishing a fire, and the inert or passive phase, which consists of properly constructing a building so that it has resistance to combustion through materials and design which will confine a fire to the locality where it originates.

Active fire control requires two definite steps, *viz.*, detection and extinction, and is either manual or automatic. The limitations of manual control are obvious. Usually, there is a too great lapse of time, first, in the detection and alarm and, second, in the assembling of the

apparatus, often from remote points. More rapid means must be used because fire must be controlled immediately.

Active fire control can be accomplished without human aid in a frac tion of the time required for manual control. Automatic sprinklers have completely revolutionized the science of fire control. When automati sprinklers operate to control a fire, the heat of the fire opens the sprinklers and the fire is quenched usually long before it would normally have been discovered. To be of maximum service, a sprinkler system must be complete. The average incipient fire can be extinguished by a man with a bucket of water, if he happens to be there. The chief value of a com plete sprinkler system is that it provides an ever present watchman on duty at every point, 24 hours of every day. Most buildings of this type are unoccupied for more than 50 per cent of the time, except, possibly by a watchman making infrequent rounds.

A fire loss, in the great majority of cases, can be reduced if appliances are installed which will place the extinguishing agent at the heart of the fire. The sprinkler system is a means of distributing extinguishing fluids which eliminate the flooding of a building. Not more than 15 to 40 per cent of the water thrown in a building by the average hose stream ever reaches the fire. The system which reduces the water damage by placing all water where it will be most effective will, as a result, also reduce the loss by fire. A typical clause found in reports on fires is "Non-waterproof floors and floor arches resulted in great damage to stock on floors below the fire." Here, again, this situation may be overcome in heavy timber construction. Through the use of saturated felt, the floors are easily made watertight, at an expense that is trifling in compari son with the cost of waterproofing the floors of any other type of con struction; it is also easy to fireproof the floors and ceilings in any room in which quick, flashy fires are liable to occur.

Improved construction of buildings, better fire protection, exper inspection at least four times per year, insistence upon "good house keeping," complete automatic-sprinkler protection, special fire pumps ample water supply from at least two independent sources, and private watchmen all result in preventing interruption to business by fire.

Exposure to Outside Fires.—An otherwise safe building may become unsafe because of the hazard of surrounding property over which the owner has no control. Protection against such exposure can be effectively provided during the construction of a building.

After a disastrous fire in Salem, Massachusetts, the only building within the burned area that remained standing, with its contents intact was one in which the wall openings were protected by wire-glass windows in metal frames, with inside shutters on which the holding links had melted, allowing them to close automatically. The sprinklers were not opened, showing that the heat within the building did not reach 155° F

Insurance Rates.—Insurance rates and fire losses maintain a fairly constant ratio. We may, therefore, consider insurance rates as a true reflection of the comparative fire hazard in occupied buildings of the several types.

The basic idea of slow-burning construction is to provide a maximum of fire protection at a minimum of cost.

The return on investments in protective equipment, brought about by reduction in insurance premiums, is carefully estimated to be 13 per cent on the cost of protecting the building from exposure hazards by installing fire shutters. There is a return of 24 per cent on the cost of enclosing vertical openings and 20 per cent on the cost of sprinkler installation.

This is not an unusual or peculiar condition. It simply reflects the actual experience in fire losses in the several types of construction. It is definite evidence that the means afforded for detection and extinction of fire are found to be of greater importance than the materials used in construction. It is proof that the engineers who determine the degree of hazard and probable loss believe that the losses from fire in an unsprinklered non-combustible building with a combustible occupancy are likely to exceed those in a building of sprinklered "mill" construction.

Permanence in industrial buildings means more than durability; it means fire safety, and that means automatic fire control. Far more consistent with sound judgment and experience is the erection of a building in which permanence of structure is assured by the use of effective fire-protective equipment rather than by mere durability of materials.

The owner who invests in so-called "permanent" materials, which fire may damage beyond any usefulness at the expense of permanent fire protection in the way of protective equipment, is courting disaster.

Burned Buildings Pay No Taxes.—Slow-burning heavy-timber construction produces a maximum degree of safety, with the utmost economy in construction. While yet in experimental stages, it gained a record of serviceability, and economy. In its present state of development, it furnishes a type of construction that may be chosen either for a new plant or for plant expansion, with the assurance that the wisdom of the choice will be confirmed from every standpoint, year after year.

It has been said that a regular slow-burning heavy-timber building is liable to be burned up once in every 2,000 years.

Proper design and care in detailing can improve even that record of good modern heavy timber mill construction.

STEEL-FRAME AND CONCRETE BUILDINGS

A large quantity of wood is used in the rough carpenter work of modern steel-frame and reinforced-concrete buildings, as well as in the interior finish. Wood is generally used for such items as door and

window bucks, furring, wooden sleepers, finished floors, and window frames and sash.

For ordinary rough work, low-grade softwoods may be specified, but for sleepers one of the decay-resisting species should be used, unless the wood is treated.

In laying hardwood floors over sleepers, the concrete floor should be thoroughly dried, and a layer of waterproof paper placed on it and under the finish floor. The air space under the floor is usually filled with concrete. A sub-floor of 1 in. seasoned softwood should alway be used.

For certain types of buildings where a wood floor is desired, the parquetry flooring is embedded in mastic and applied directly to the concrete construction. The material should be thoroughly dry to avoid squeaking. When wood is used as rough framework for architectural features, it is generally covered with sheet metal or metal lath, and plaster.

Doors with wood cores covered with metal, if fabricated in accordance with well-established underwriter or building-code specifications, are usually acceptable as fire doors.

Wood-block floors consist of blocks laid with the end wood exposed and embedded in a sand cushion or asphalt. They are often used in work shops and where traffic is heavy.

ROOF AND BRIDGE TRUSSES

There are numbers of different types of trusses used in timber construction, but the most common varieties are the *king-post*, *queen-post*, *Howe*, *scissors*, *hammer-beam*, *bowstring*, and *lattice trusses*. Figure 109 illustrates trusses in which the chords and compression diagonals are of wood and the vertical tension members are often of steel rods. It is easier to frame a compression joint than a tension joint.

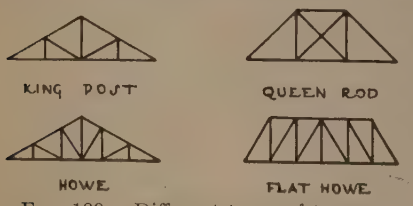


FIG. 109.—Different types of trusses.

Roof loads should be applied by purlins at the panel points, to avoid bending moments in the upper chord, and, hence, the type of truss to be used in any particular case is somewhat dependent upon the span and upon the length of the panel or bay.

King- and queen-post trusses are satisfactory for span lengths up to about 30 ft. For spans of more than 30 ft., the Howe type of truss is satisfactory, as are also the bowstring and lattice types. Scissors and hammer-beam roof trusses have a high pitch and a maximum clearance and are used mostly in public halls and churches for ornamental effect. The Howe truss is the usual type for highway and railroad wooden-truss bridges.

FIG. 110.—Roof truss construction used at Esslingen Station, German Government Railways.

FIG. 111.—Roof truss for warehouse construction at Stuttgart Station, German Government Railways.

Trusses of king post, flat Howe, or Warren types are generally used for flat roofs. The Howe truss is the type most commonly used for flat roofs and for roofs with only a slight pitch and is also in wide use for railroad bridges; but when it is so employed, counterbraces are needed to take care of the moving loads. The queen-post truss is less frequently used and mostly only on short spans.

In Figs. 110 and 111 are shown the use of wooden roof trusses and wooden roof systems, as applied to concrete and brick buildings. These examples are from modern German practice and show the economic possibilities of wood in conjunction with masonry.

Truss Details.—The most important and, at the same time, the most difficult phase of wood design is the proper detailing of truss joints. The truss members themselves are easily computed, and it is seldom that the main sections of a truss fail. A case where truss details are amply sufficient for the stresses that may come on them, and the main members are insufficient, rarely, or never, occurs. The connections and details, however, are often neglected, and practically all the failures that occur are directly attributable to faulty joint details. It is important to arrange to have the center lines of all members meet at a common point, located at the intersection of the center lines of the truss members; otherwise, bending moments are set up, which must be provided for in the design. All compression joints should be checked for bearing, with due allowance for safe bearing values on surfaces inclined to the fibers. Authorities differ as to whether the Jacoby or the Howe formula should be used, and tests have apparently proved that first one and then the other was correct.

Simplicity in the design of connections is desirable, in order that proper construction and erection may be insured. There are many different types of end joints; but a decision as to which is the most suitable one to use to meet any particular set of conditions depends upon various elements, such as type of truss, kind of support, and clearance. The end joint must transmit to a lower chord the horizontal component of compression in the rafter or end post. Steel plates bolted or lag screwed, cast-iron shoes held securely on the top of the lower chord, steel plates bent around the end of the rafter or end post with or without tables may be used to accomplish this purpose; or, the end post may butt against block tables set into the top of the lower chord and securely bolted.

Where rather large stresses must be provided for, the joint shown in Fig. 112 is particularly satisfactory. This joint can easily be adapted to different loads. It is an economical joint, for the dimensions of the main plate are governed only by the direct stresses of shear and tension and not by the thickness of the end of the plate, bent down as a lug, as is sometimes done, to provide resistance against horizontal stresses. It has been designed so that the full thrust of the end post will be taken up either by the horizontal shear developed in the lower chord or by the horizontal

component of the tension developed in the diagonal bolts. It has been proved, and is now generally admitted, that these two systems will not operate simultaneously. Either one will resist the stresses to the point of failure, before the other comes into play. The bearing is taken care of by steel tables, the number of which can be varied to suit the loading. Note the use of the oak wedge block under the end post. Where hardwood pins or keys are used, they must be well seasoned, for a slight

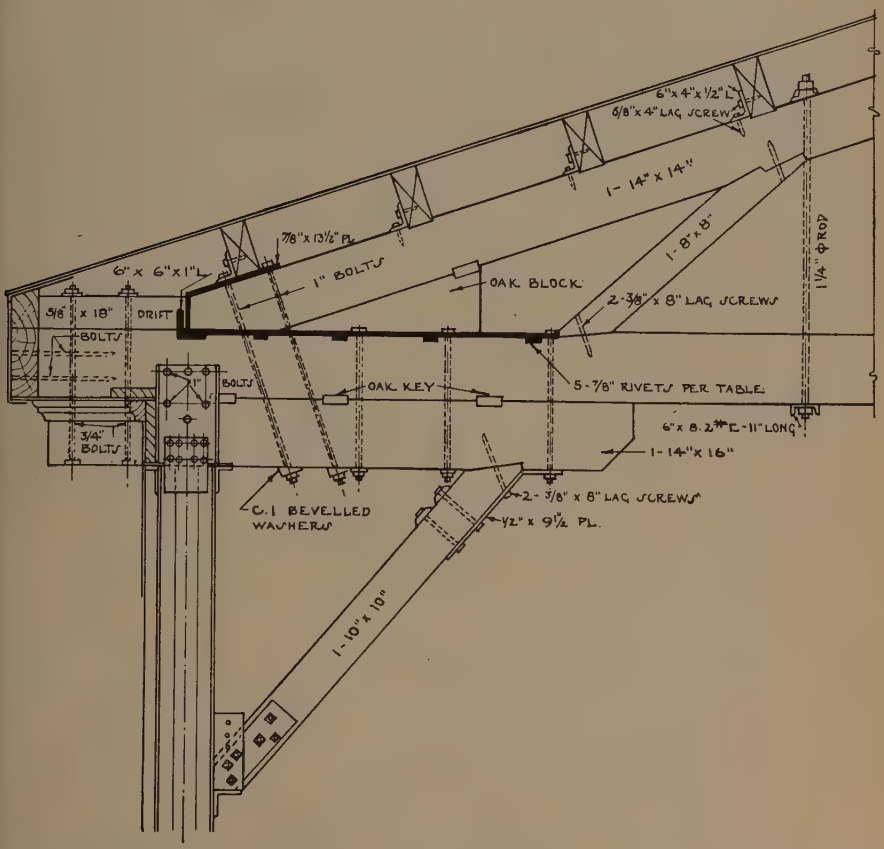


FIG. 112.—End joint detail for a roof truss, Union Pacific Railroad locomotive shop.

shrinkage will permit the point to slip. Figure 112 also shows a simple method of securing heavy purlins to a rafter or to the end post of a truss, by the use of clip angles and lag screws. On flat roofs, purlins are usually just notched and toenailed to the top chord of the truss.

Figure 113 shows a modification of the joint in Fig. 112 where only one table is used, but, as usual, it is riveted to the bearing shoe. The rivets, however, are generally countersunk at the bottom of the table.

Figure 114 illustrates the end connection of a roof truss with a span of 30 ft. 3 in., at the end of a passenger station on the Michigan Central Railroad. The 2- by 6-in. timbers which are bolted through the lower chord to the masonry wall are sills over which the roof rafters are framed.

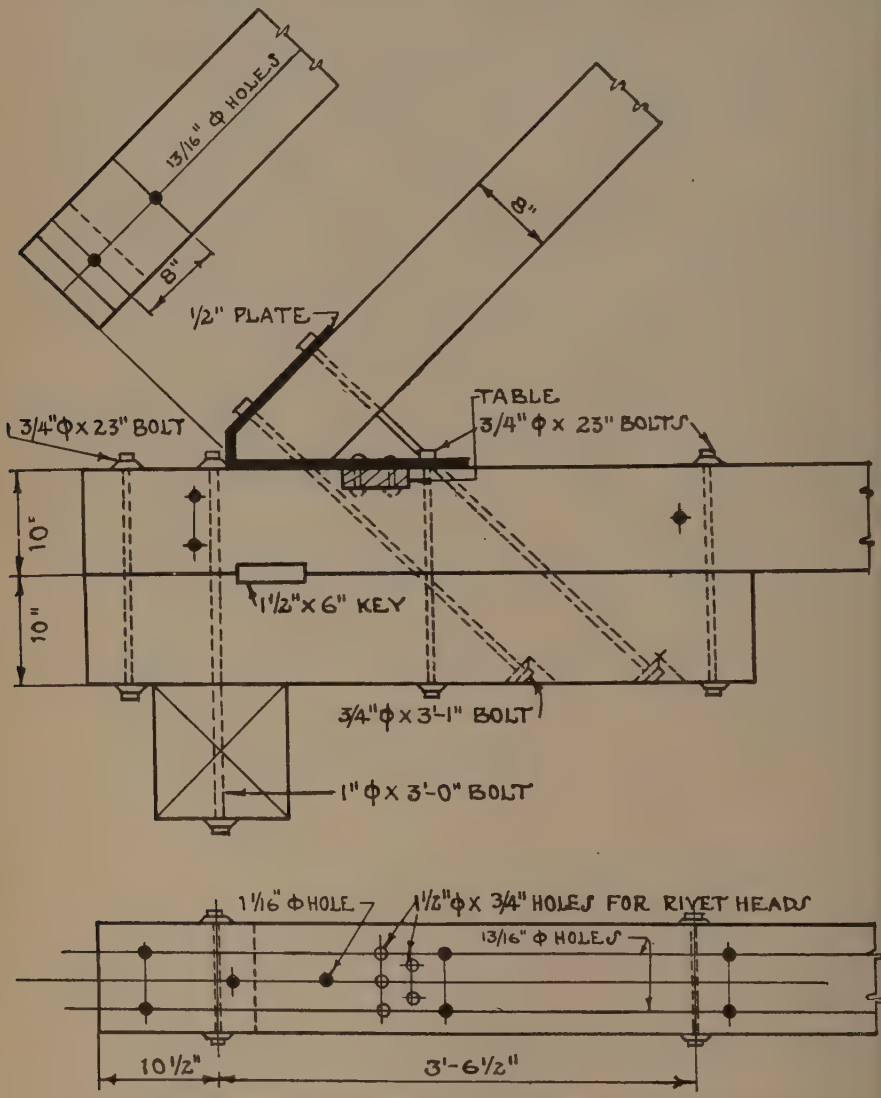


FIG. 113.—Detail of end joint of a 55-ft. truss, Louisville and Nashville Railroad.

The oak bolster affords bearing surface for the washer of the 1-in. diagonal bolt and serves to stiffen the lower chord. The members framing into the wall below the truss are 2- by 6-in. ceiling joists. These joists frame into 4- by 8-in. members extending between trusses at the panel

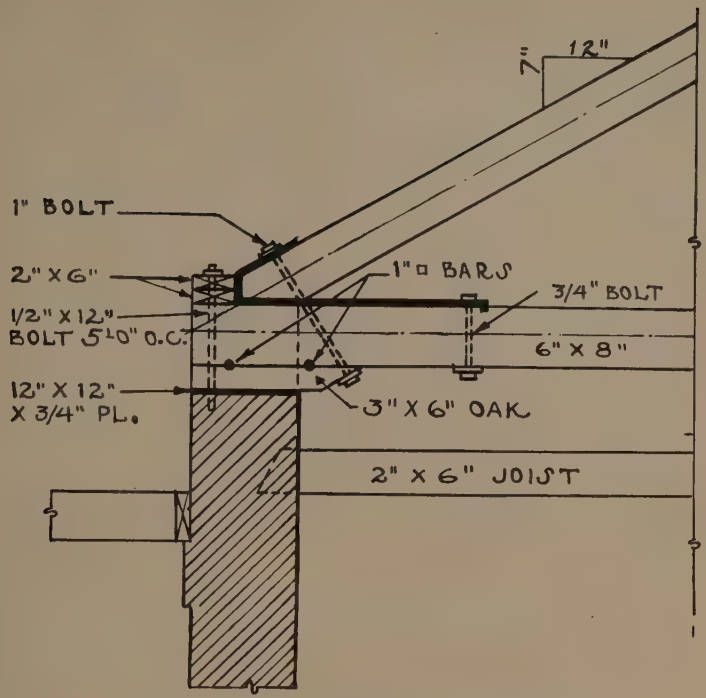


FIG. 114.—End connection of a roof truss.

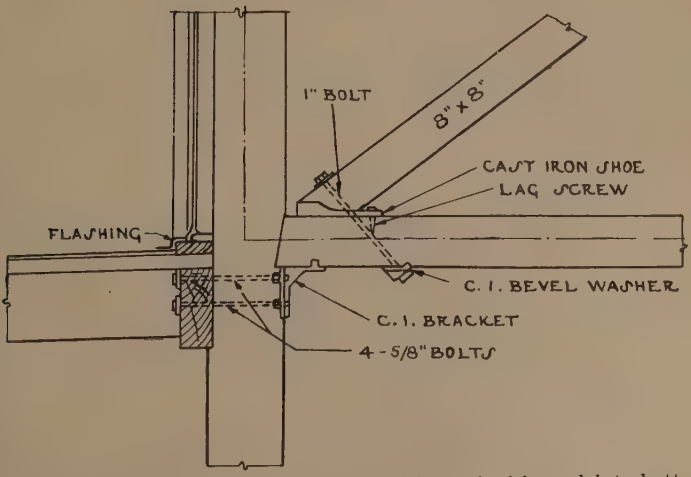


FIG. 115.—End joint with C. I. shoe, lag screwed instead of lugged into bottom chord.

points and are supported by the vertical tie-rods of the trusses, which are continued down the required distance below the lower chord.

Figure 115 illustrates a cast-iron shoe, lag screwed to the bottom chord. This type of end joint is a good one, if properly designed. In this figure, the cast-iron plate is not lugged into the chord, and, hence, either the two or three ¾-in. lag screws or the 1-in. bolt must resist the thrust in the 8- by 8-in. batter post. The ¾-in. lag screws are good for a recom-

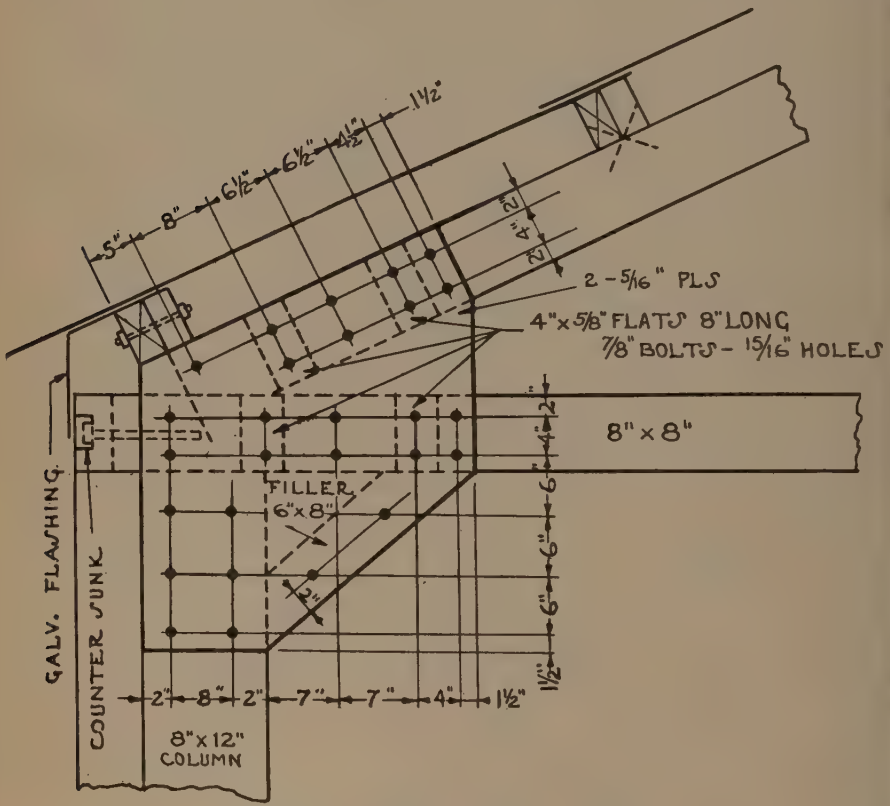


FIG. 116.—End joint detail of roof truss.

mended stress of only 1,030 lb. Three such screws would be good for only about 3,090 lb., which would be obviously of little value for the horizontal component of the beam which has an actual area of approximately 56 sq. in.

Figure 116 illustrates a detail that is somewhat similar to a gusset-plate joint in steel design. In principle, this type of joint is ideal, but practically it is open to some objections. It cannot be inspected for defects, and it is almost impossible to frame notches in the timber for the steel tables so that the tables will have equal and uniform bearing.

A somewhat similar joint consists of gusset plates lag screwed to the sides of the end post and bottom chord, no tables or lugs being used. The holes in the steel plates are drilled $\frac{1}{32}$ in. larger than the shank of the lag screw.

To secure a good joint in which initial stresses will not be developed, the holes for screws in the truss members should be bored the same diameter and depth as those for the shank, and the hole should then be continued with a diameter equal to the diameter of the screw in the root of the thread. Lag screws should be screwed and not driven into place. They should be placed from opposite sides of the member, about half

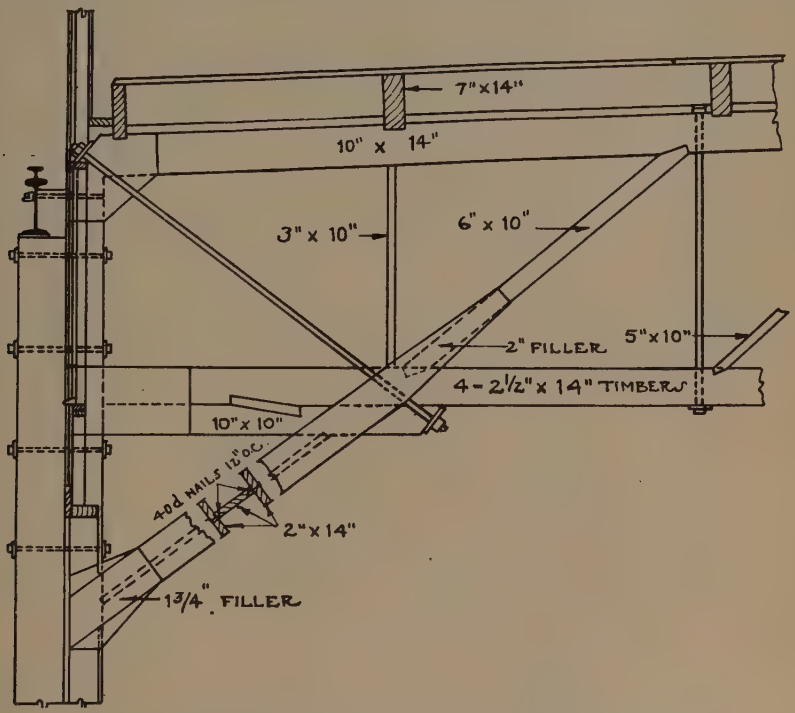


FIG. 117.—End detailing and knee bracing in a 70-ft. Howe roof truss.

being placed from one side and half from the other. This joint requires a large number of screws, but it is a good joint for high-pitched roof trusses set on posts, because the plates can be fastened to the sides of the posts and thus furnish additional lateral stiffness to the truss. If bolts are used with the gusset plates in this joint, it will be found that the opposite ends of the holes do not match exactly with the holes in the steel plates; hence, the bolts must be sprung into place, creating large initial stresses in the bolts and decreasing their shear-resisting qualities.

Rather unusual end detailing and knee bracing in a 70-ft. Howe roof truss over a pier shed in the port of Seattle is illustrated in Fig. 117. The

compression diagonal in the end panel has been replaced with a tension rod bearing against the bolster. The H section used for the knee brace is interesting. It consists of three 2- by 14-in. boards with necessary fillers and is secured to both the column and the second-panel diagonal.

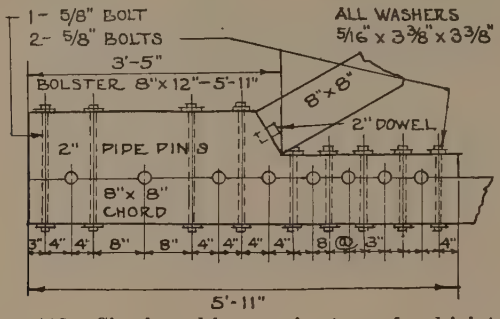


FIG. 118.—Simple and inexpensive type of end joint.

Figure 118 shows a fairly simple, inexpensive type of end joint. When this joint is used, it is important to insist that the timber be well seasoned, since even a slight shrinkage will loosen the pins and permit slippage.

Intermediate Joints for Trusses.—Truss diagonals must have sufficient bearing area to resist thrust. The usual method is to indent the chords just enough to obtain bearing, as indicated in Figs. 117 and 119.

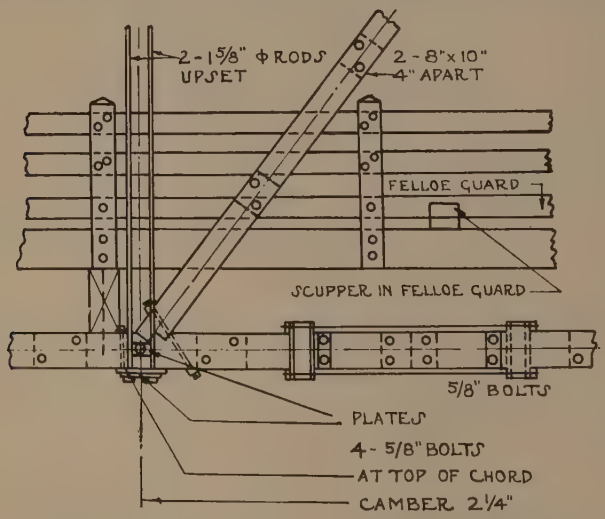


FIG. 119.—Lower chord detail, 120-ft. Howe truss, Oregon State Highway Commission.

In using unit bearing stresses in details, such as those illustrated, allowance must be made for inclined bearing. The indents in the upper or lower chords reduce the effective areas of the section, but if the joint in

the top chord which is in compression is made tight, then, theoretically, this reduction in section area can be ignored. Actually, the joints are seldom tight, and, as a consequence, the section area suffers. The lower chord is in tension, and here the depth of indent or framing cut must be considered; and, in all cases, the design should aim to minimize this cut. All such joints require skilful carpentry to secure correct angles, depths of cut, and, above all, uniform and even bearing; also, there is bound to be some eccentricity at the panel points, since the forces act through the center of the uncut or net sections rather than through the middle of the cut section.

The experience of the Oregon State Highway Commission has shown several features, which are illustrated in Fig. 119, to be highly desirable. Diagonal bolts, for example, are used at all joints instead of only at the end joint. These bolts reinforce the shear tables and add a certain amount of potential strength in case a shear table splits or shears off in service. Clinch bolts and packing members are used on all multi-ply members. Scuppers and drip boards in the felloe guards are used to prevent premature decay in the edges of the decking. Experience has shown that decay practically always starts either between the decking and the felloe guard or along the outside ends of the decking. The drip boards protect the end; and by giving the bridge a camber and using scuppers along the sides, the water is quickly drained off. The joint between the decking and the felloe guard is further protected by using an asphaltic-cement fillet.

Cedar-shingle shims are used between the decking and the felloe guards, to insure a snug, tight joint; 2- by 6-in. laminated decking is frequently used. The joint thus formed excludes moisture and eliminates a large part of the vibration, strains, and movement of the deck under traffic and causes the felloe guard to act as a continuous waling strip, aiding in the distribution of concentrated deck loads.

Many highway engineers now prefer, however, to raise the felloe guard from the flooring, either by blocks, spaced 4 ft. apart, or by securing the felloes to the truss.

Metal angle blocks are often employed to avoid cutting the truss chord, as illustrated in Fig. 120, which shows the main diagonal and counterframing into the lower chord of a 125-ft. railroad Howe truss. This joint, which must be designed to take care of the eccentric action of forces, shows, also, a method of supporting the floor beams. The separators which are provided for ventilation between the floor beams should be noted.

The advantage of the detail shown in Fig. 121, in which butt blocks are utilized, is the preservation of full bearing areas by the use of simple carpentry methods. In many cases, this joint has proved to be very effective.

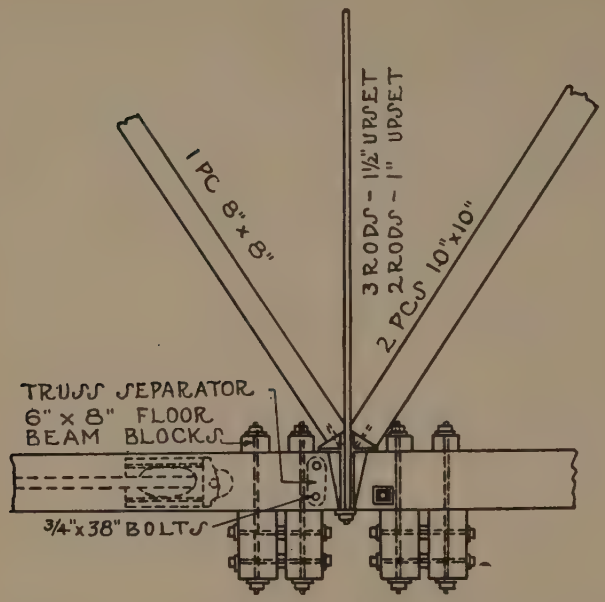


FIG. 120.—Intermediate joint showing use of angle block in 125-ft. Howe truss on Southern Pacific Railroad.

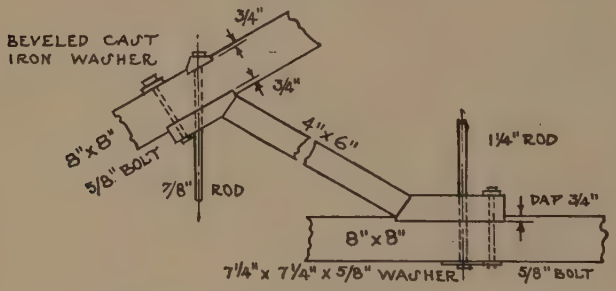


FIG. 121.—Use of butt-blocks in intermediate truss joint.

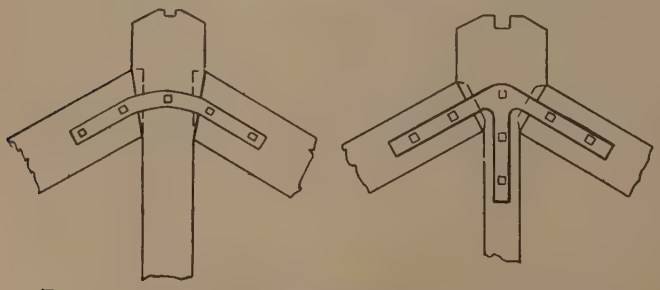


FIG. 122.—Two methods of fastening King posts to rafters.

Figure 122 illustrates two methods which may be used at the apex of a king-post truss to fasten the vertical king post to the rafters. It will be noted that the ends of the rafter are notched into the sides of the king post; this, in addition to the use of metal straps, gives a very stable and satisfactory joint.

In Fig. 123 is shown a simple and effective method of securing the rafter of a king-post truss to the tie-beam or lower chord. The use of the strap as shown in the figure makes a strong, efficient joint, since the strap can be tightened by means of the nuts and the plate washer which bears on the top of the rafter. The small notch made in the beam to inset the strap causes little weakness, which the advantages more than offset. The end of the rafter may be simply notched into the tie-beam, or it may be mortised, as indicated by the dotted line in the figure.

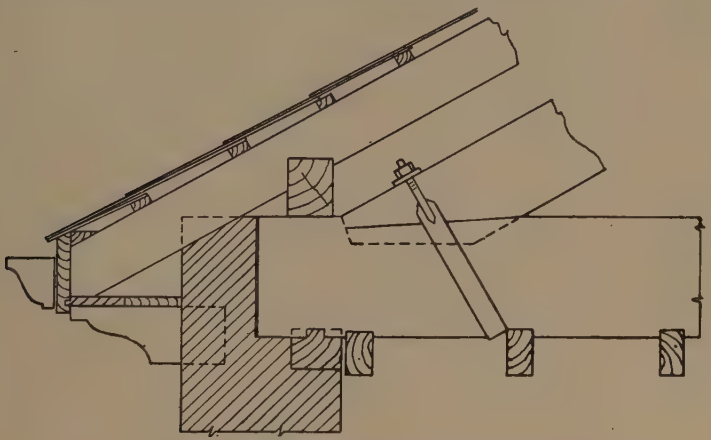


FIG. 123.—Method of securing rafters of a King-post truss.

The plan and elevation shown in Fig. 124 illustrate a method of providing support for 10- by 16-in. roof beams. This illustration is a good example of the use of corbels to take the vertical thrust from the knee braces. The corbels are dapped into the post 1 in., and, in addition to bolts, 2-in. oak pins are used. Mortise-and-tenon joints between the roof beams and top bolster, with key wedges, are an interesting feature of this detail. The roof sheathing, in this case, 2 in. nominal D. & M. material, was placed directly on the 10- by 16-in. beams.

Roof trusses with straight rafters are usually of the simple, triangular king-post or English type. The more elaborate trusses have been developed from the ordinary couple roof by adding a horizontal tie to keep the rafter from splitting and by then inserting a vertical tie to support the middle of the lower tie or chord, especially for the longer spans.

Figure 125 illustrates a Howe truss on the roof of an airplane hangar at Grays Harbor, Washington. These trusses have a span of 42 ft. and

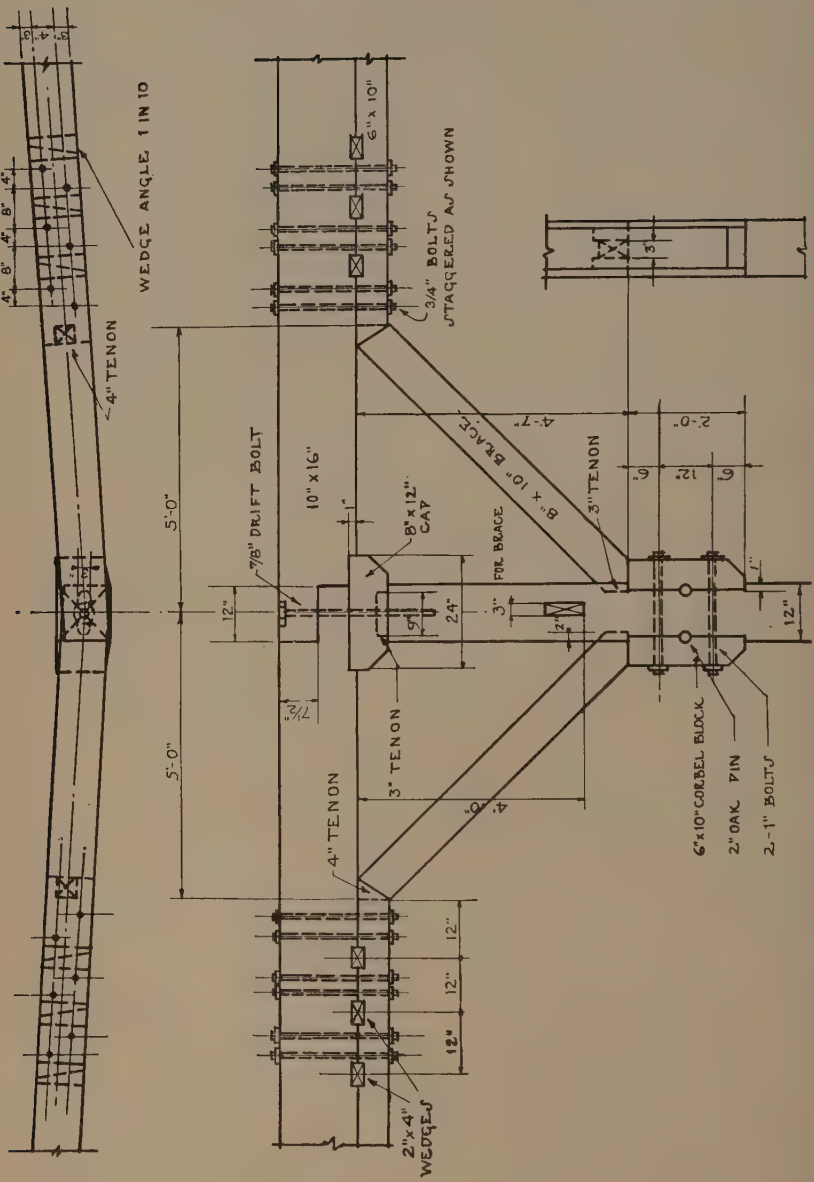


FIG. 124.—Plan and elevation of a method of providing support for heavy roof beams.

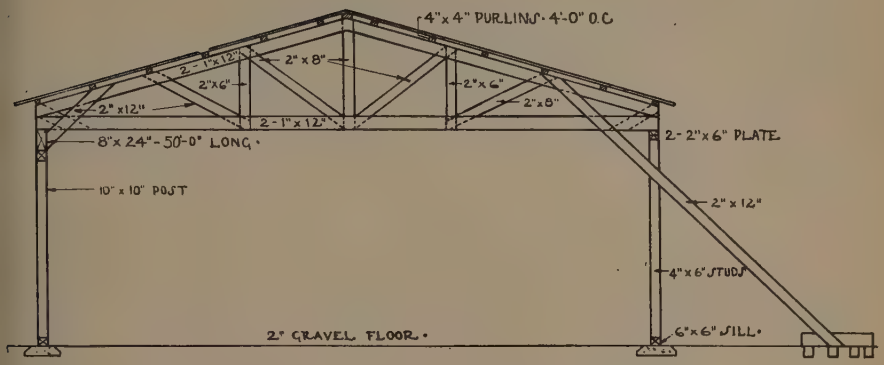


FIG. 125.—Howe truss, airplane hangar roof.

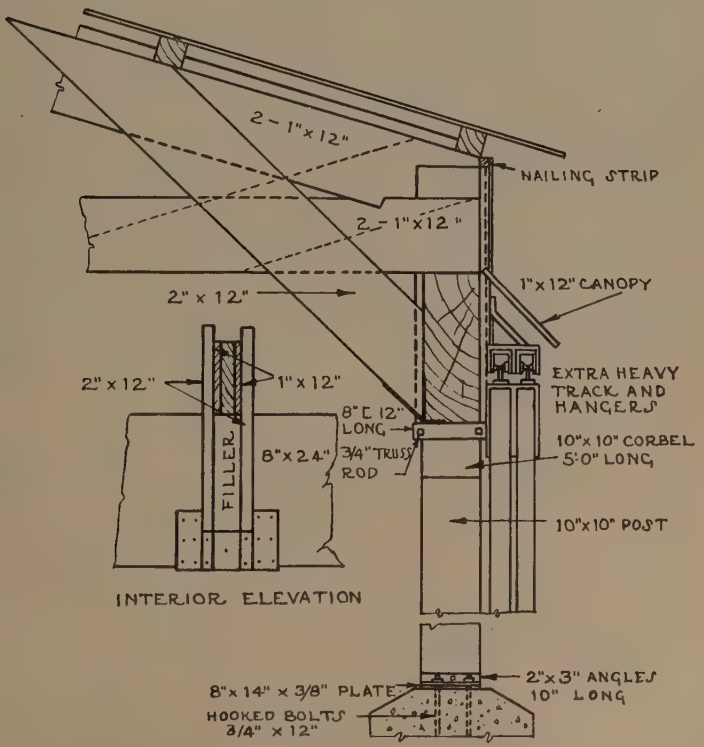


FIG. 126.—Detail of roof connection and post anchorage of Howe truss shown in Fig. 125.

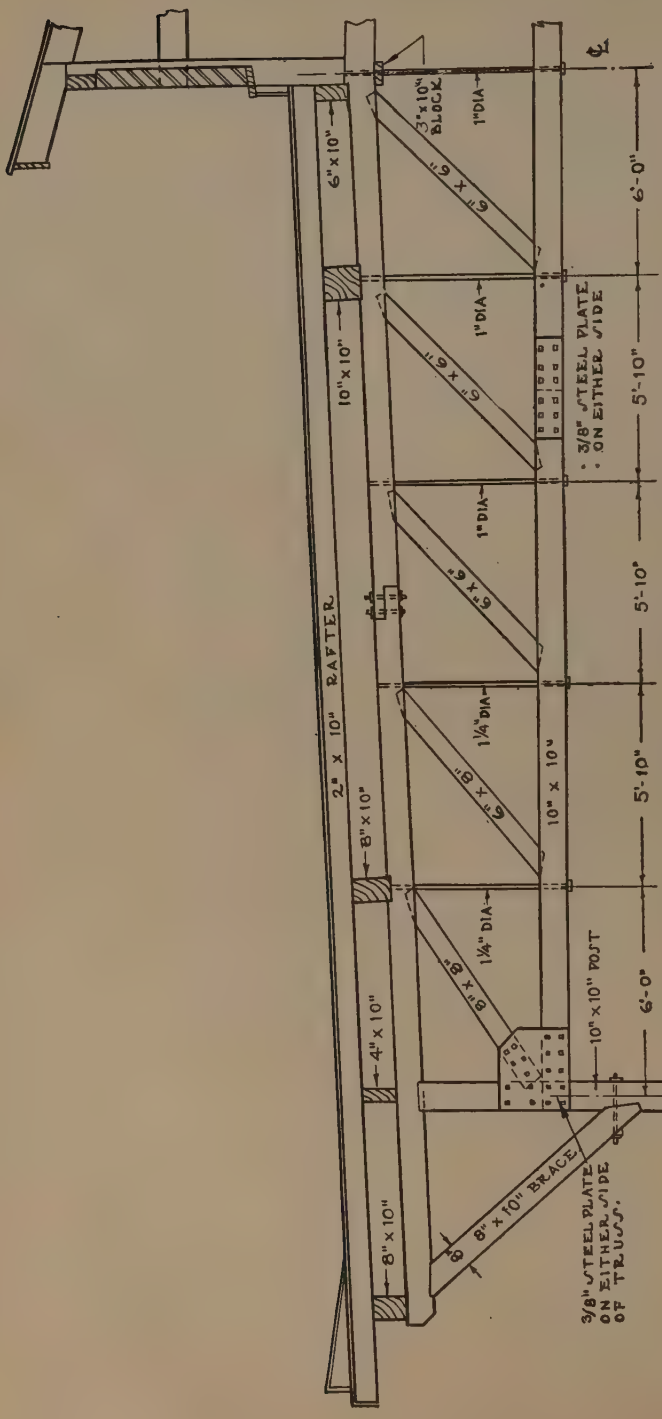


FIG. 127.—Roof truss with Monitor construction, Atlantic Coast Line Railroad.

are spaced 8 ft. on centers. The building is approximately 150 ft. long. Two 2- by 12-in. wind braces tied to the ground are used at the third points of the building, as indicated. The heavy 8- by 24-in. stringer shown on one side is used to support the door tracks and hangers.

Figure 126 illustrates the details of the roof connection as well as of the post anchorage. The posts are spaced 50 ft. on centers and support the stringers.

Figure 127 illustrates one-half of the roof truss, with monitor construction over the center of the truss, used in a roundhouse of the Atlantic Coast Line Railroad.

FIG. 128.—Highway bridge of Howe truss type.

Figure 128 shows a highway bridge of the Howe truss type. The picture was taken before the bridge was housed and is clear enough to indicate the lower chord splices, the angle blocks used to furnish bearing for the diagonals, and, also, the upper diagonal bracing and method of supporting the floor.

Figure 129 shows this same bridge after it was covered or housed. The half end view and section of housing are shown in *Plate* 66.

The section shown in *Plate* 66 is taken through one of the 6-ft. by 8-ft. 6-in. windows in the side of the housing. The following general specifications apply:

Housing to be No. 1 common (may be local timber) sized on one side and one edge.

Battens to be sized on four sides.

The exterior surface of the housing, including all window casings and that portion of the truss visible from the outside, to be given two coats of approved lead and oil paint; color as directed.

The interior surface not otherwise covered shall be sprayed with one coat of an approved cold-water paint.

Roof shingles to be predipped in an approved preservative, before placement. The entire roof surface to be given two coats of dark-green shingle stain of an approved composition.

Use this design for housing details only.

For truss detail, see truss-design drawings.

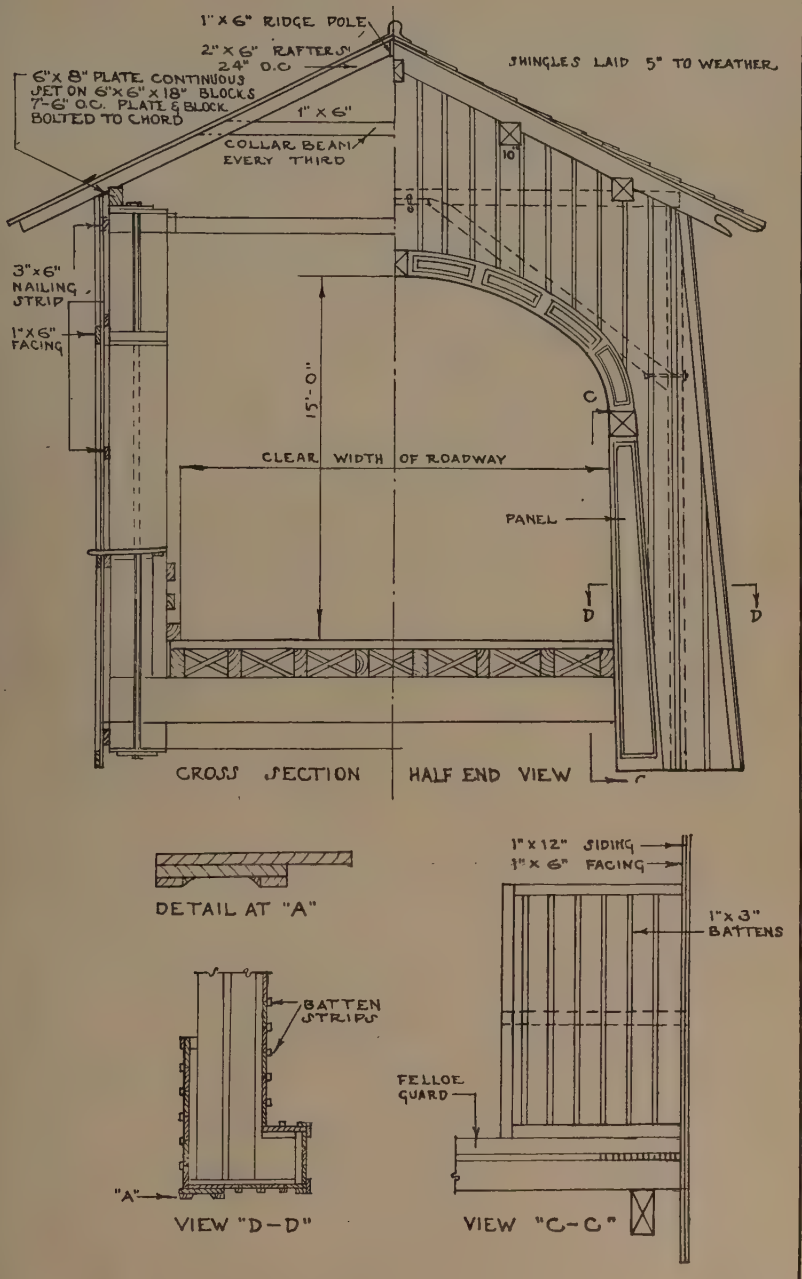
Note that nailing strips are fastened to the main truss, to support the housing.

FIG. 129.—Housed highway bridge of Howe truss type. Same bridge as shown in Fig. 128

Where the siding is fastened too rigidly, shrinkage of the truss members may pull the siding off the strips. To avoid this, nail the siding vertically as shown in the figure (one nail at each strip with two at ends is good practice), and cover the joints between adjoining members with battens nailed to one piece only, so that the batten can slide freely over the other siding piece.

Hammer-beam Trusses.—Sometimes, a combination of a hammer beam and scissors truss is used for churches and public halls, as indicated in Fig. 130. Modifications of these types of trusses are being used more and more by architects, on account of the readiness with which effects in design can be obtained. Combinations of these two trusses with each other, or of the hammer beam with an A truss, provide flexibility in design. The characteristics of such combinations are:

1. High pitch and maximum clearance.



HOUSED HOWE TRUSS BRIDGE.

Plate 66.

2. Horizontal thrust at supports require tie-rods or thick walls o buttresses.

3. Ornamentation or architectural effects rather than economic us of wood. Laminated beams often used with joints masked by moldings and decorative features.

Deflections are not of great importance in this type of truss, as the timbering is exposed. Shadow effect and appearance from below are large factors in architectural design.

Figure 131 shows decorative treatment for a church truss of the collar-beam type, with king post, in Trinity Church, Monessen, Pennsylvania.

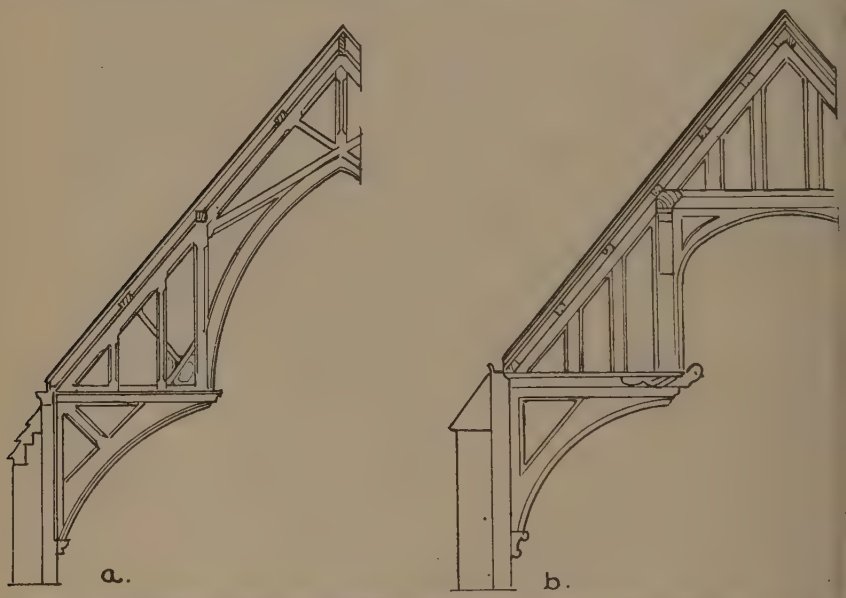


FIG. 130.—(*a*) Hammer beam with scissors truss above: (*b*) hammer beam with *A*-truss

Figure 132 shows interior elevation of one bay. Note chamfered beams curved braces, and large, squarish sections, instead of the narrow one indicated by an economical engineering design.

Figure 133 shows elevation of main hammer-beam trusses with arch used in one of the graduate college buildings at Princeton University.

Bowstring and lattice trusses are commonly used for roof trusses, th bowstring type being used frequently for bridge arch centers durin erection. Figure 134 shows a typical section and elevation of a bowstrin truss. The upper chord is built up of several pieces of 3-in. boards, glue and nailed together to form two parallel timbers, between which the we members are fitted and bolted as shown.

Figure 135 illustrates a lattice truss with chord members of simila construction, except that 2- instead of 3-in. boards are used.

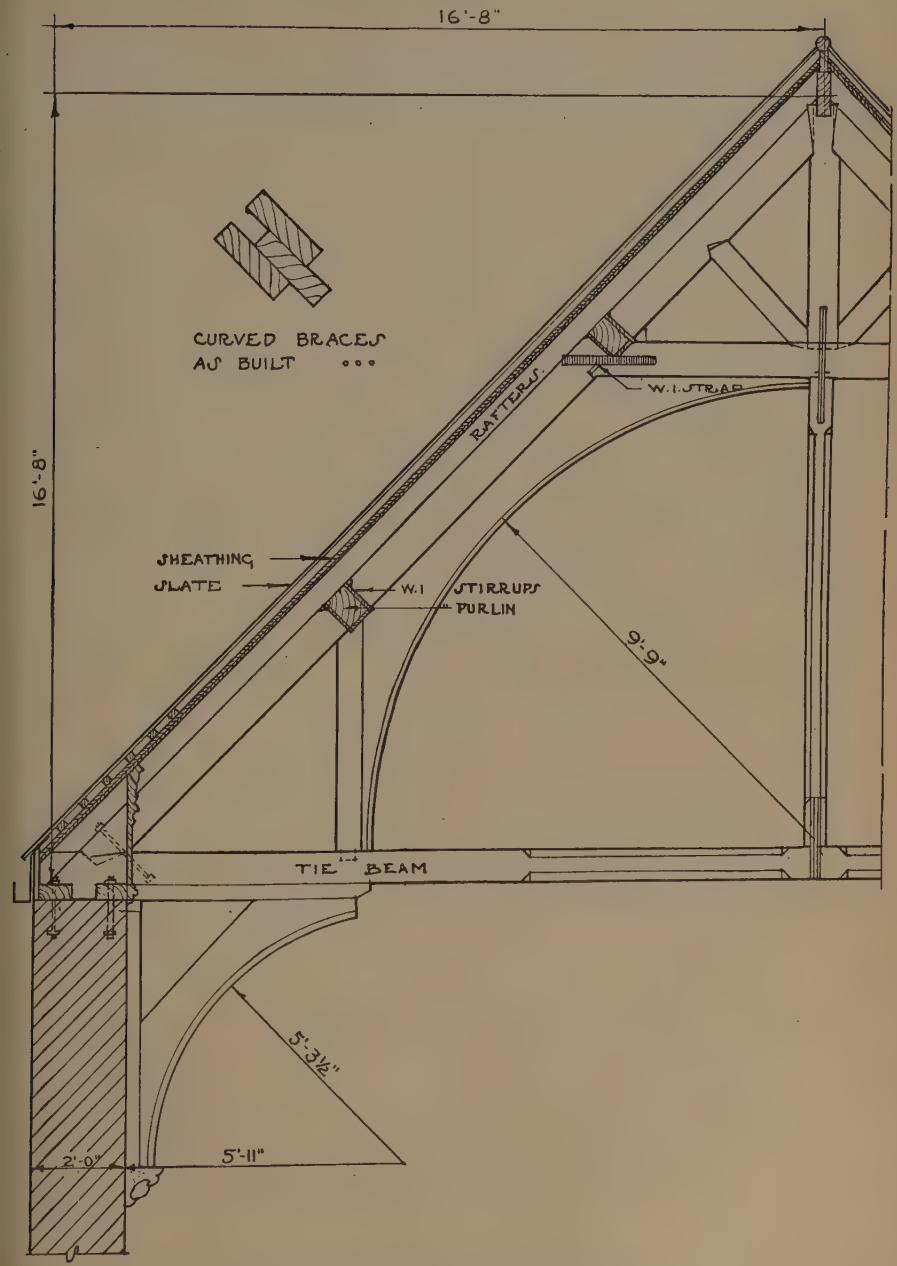


Fig. 131.—Collar-beam truss in church.

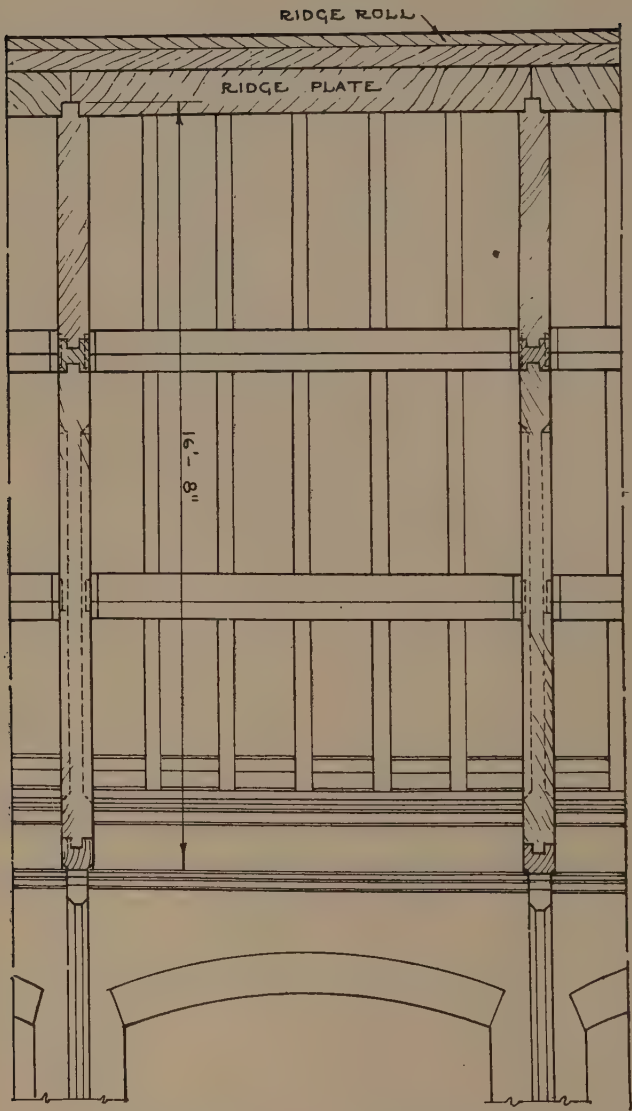


FIG. 132.—Interior elevation of one bay of church roof (see Fig. 131).

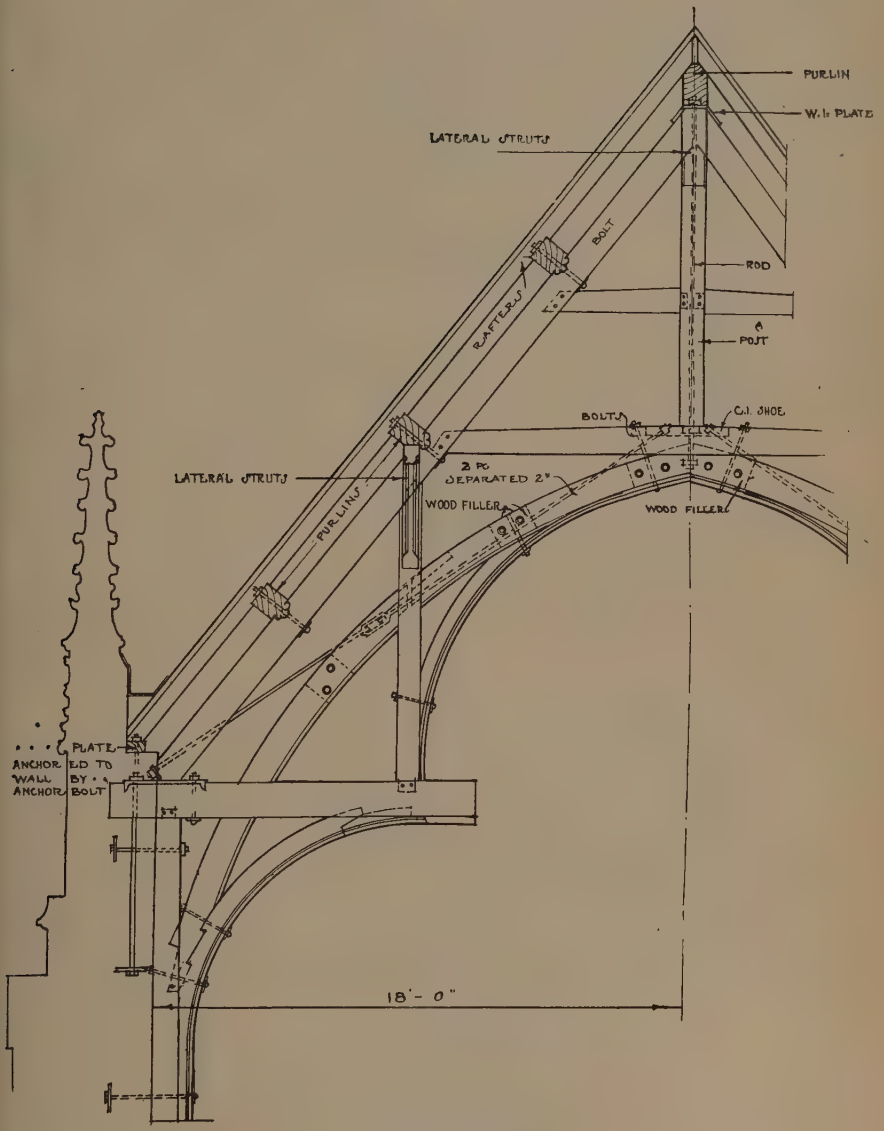


FIG. 133.—Nave trusses.

Figure 136 shows another type of bowstring truss, in which 2-in. pieces are bolted together horizontally and vertically. The roof joists are laid directly upon the upper chord, and the sheathing is laid on the joists. The height of these trusses as usually designed is one-eighth of the span length. Bowstring and lattice trusses similar to those illustrated are used for spans up to 150 ft. and are particularly suitable where design

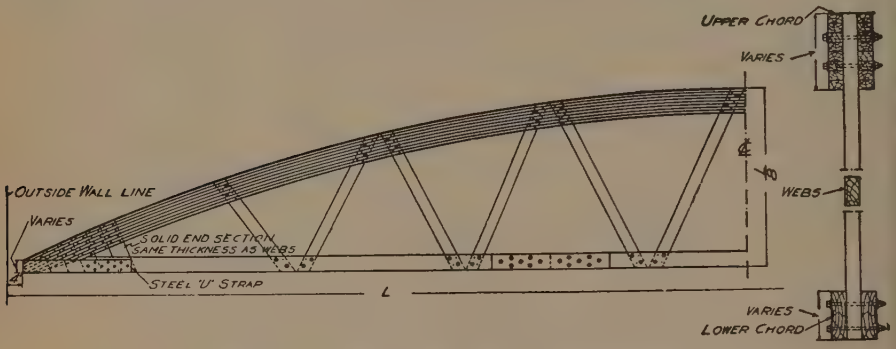


Fig. 134.—Detail of McKeown bowstring truss.

conditions require clear floor space and the absence of supporting posts. They are especially adaptable for garage and warehouse construction.

Figure 137 illustrates a series of bowstring trusses used in an airplane hangar. In the spring of 1927, when the White House at Washington, District of Columbia, was being repaired, similar trusses were employed for the temporary roof construction.

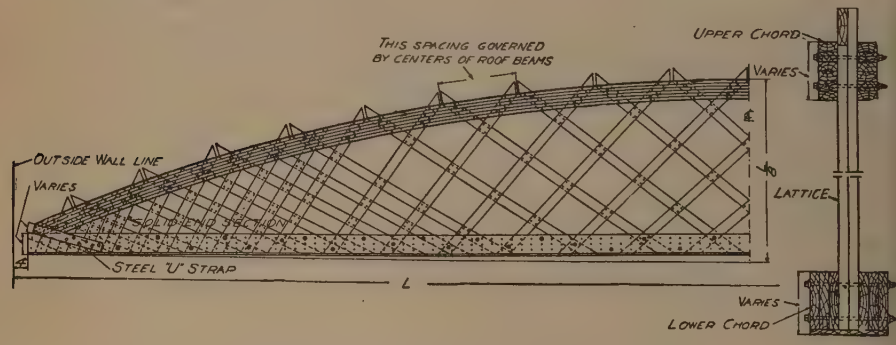


Fig. 135.—Detail of McKeown lattice truss.

Plate 67 illustrates another type of lattice roof truss, in which some interesting details are shown. In the bowstring truss illustrated in Fig. 138, the intermediate truss members are 12- by 14-in. posts, tenoned into the top and bottom chords. Tie-rods are used on either side of the posts extending down through the lower cord to support the 12- by 14-in. cross floor beams, which, in turn, carry the 8- by 14-in. stringers.

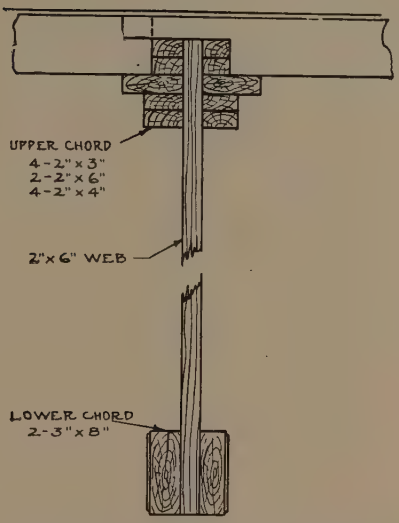


FIG. 136.—Summerbell bow-string truss.

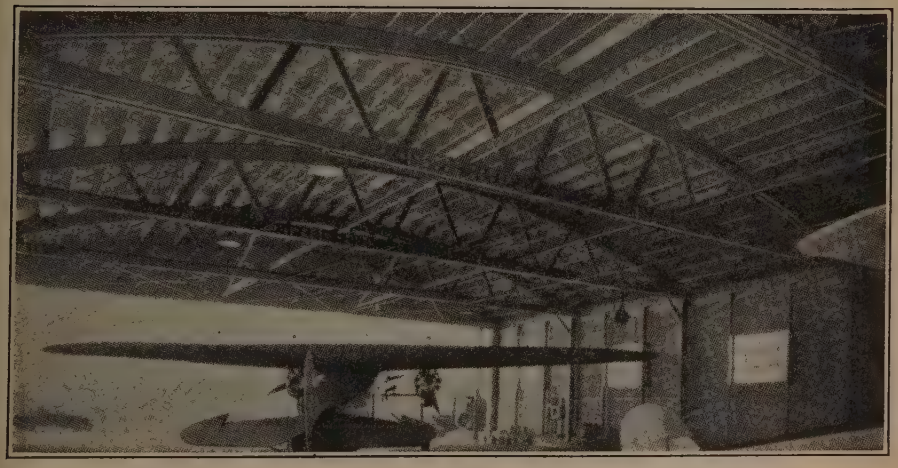


FIG. 137.—A series of bow-string trusses used in an airplane hangar.

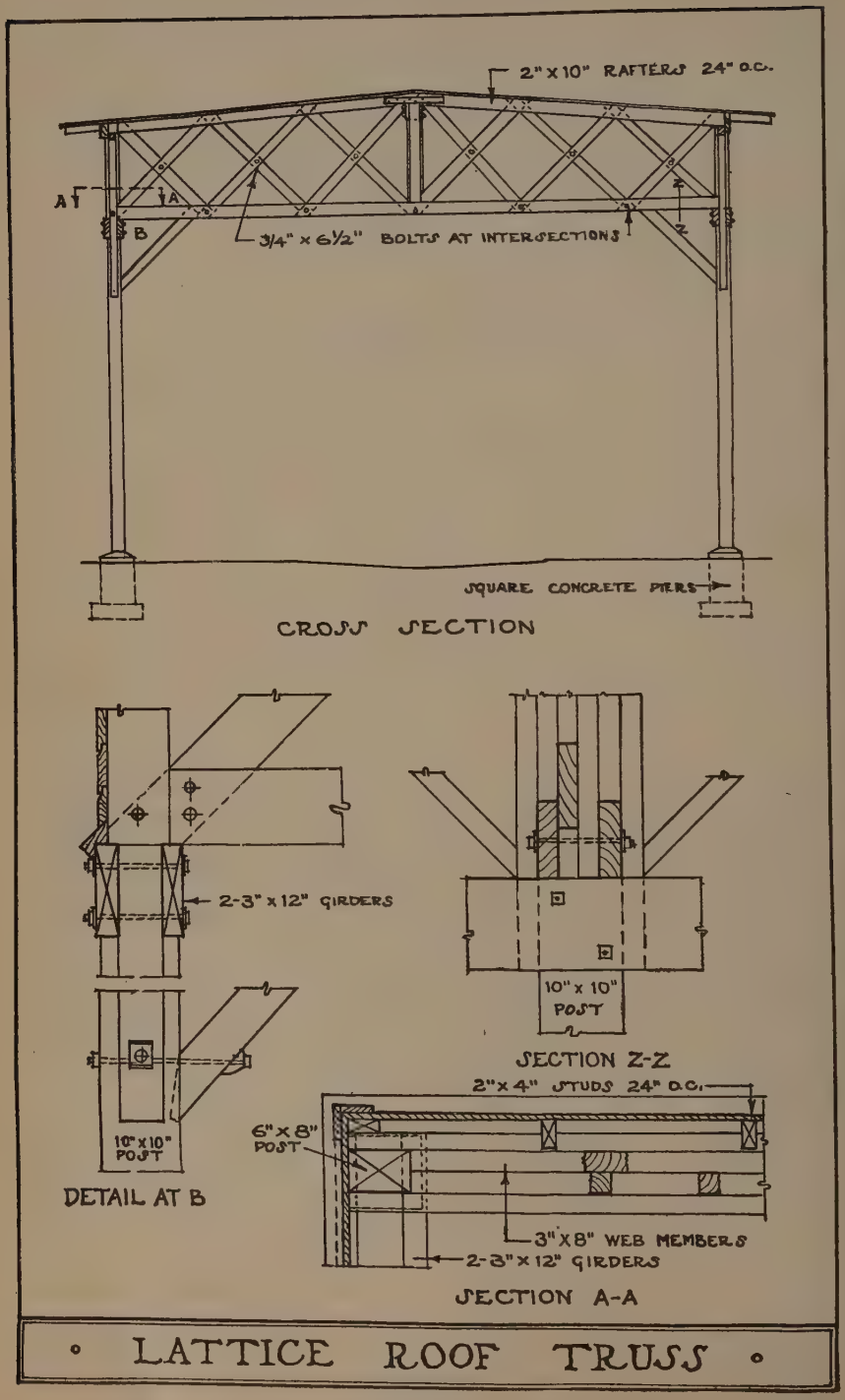

2"x10" RAFTERS 24" O.C.
A
A
B
3/4" x 6½" BOLTS AT INTERSECTIONS
Z
Z
SQUARE CONCRETE PIERS
CROSS SECTION
2-3"x12" GIRDERS
10"x10" POST
DETAIL AT B
10"x10" POST
SECTION Z-Z
2"x4" STUDS 24" O.C.
6"x8" POST
3"x8" WEB MEMBERS
2-3"x12" GIRDERS
SECTION A-A
LATTICE ROOF TRUSS

Plate 67.

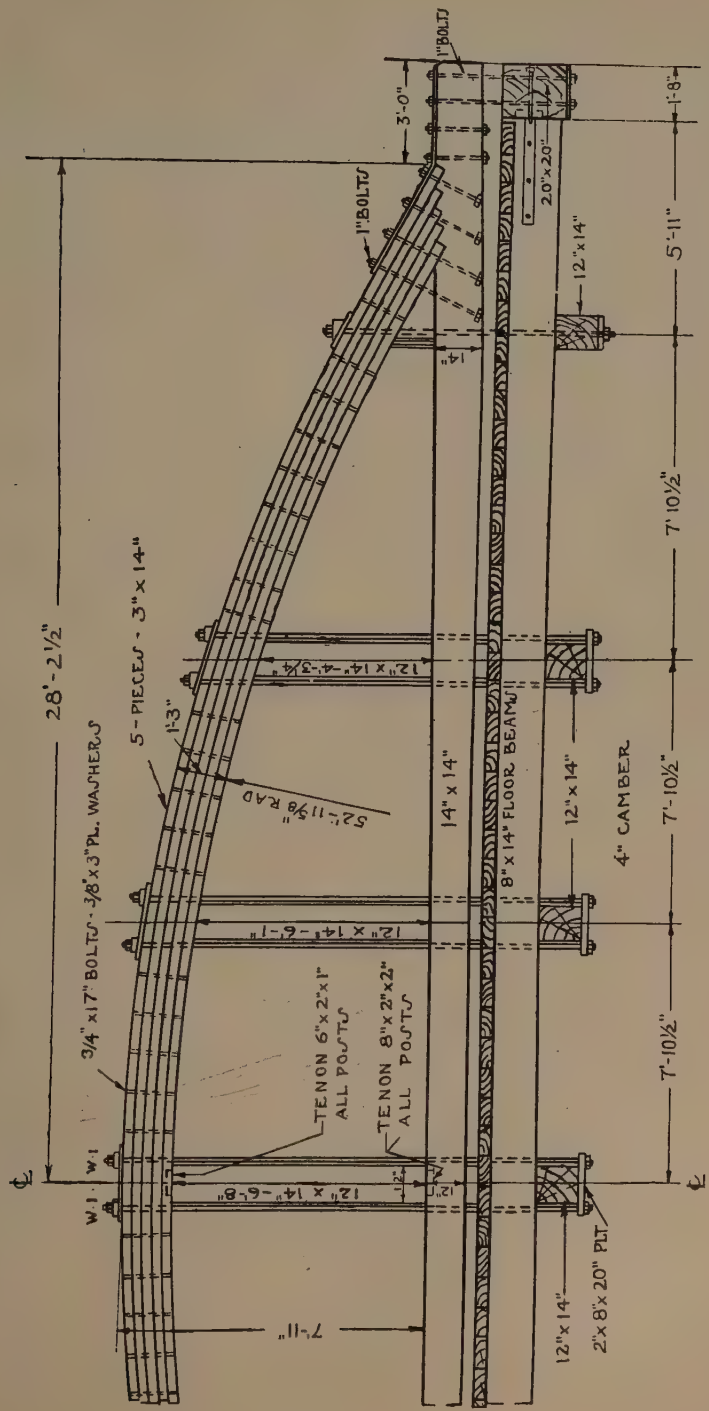


Fig. 138.—Bow-string truss, D. L. and W. Railroad.

Four-inch flooring is laid on these stringers. A 3-in. finish flooring is laid over this subflooring between the trusses.

Figure 139 shows sections cut through the trusses and floor framing of the bridge illustrated in Fig. 138. Figure 140 shows the application of bowstring trusses to the roof of a one-story garage built in Tacoma, Washington.

Lamella Roof Construction.—The lamella type of roof, designed by German engineers and introduced into the United States in 1925, is growing in use. The lamella is a specially designed piece of lumber; it is the standardized unit for the lamella roof, just as the brick is the standardized unit for a brick wall or building. Lamellas are joined together in netlike fashion, to cover large spaces in one clear span, thereby forming a uniform wooden arch. They are cut in various standard sizes from 1- by 8-in. to 2- by 14-in., and in exceptional cases, even larger; they are curved on one side and beveled on both ends, as shown in Fig. *a*, *Plate* 68. Clear spans up to 130 ft. have been constructed.

The netlike shape of the lamella construction is demonstrated in Fig. *b*. The lamellas used for one roof are all of the same size. There are right and left lemellas, and all have holes drilled at the ends and at the center, to receive the bolts. The lamellas are securely bolted together by standard steel bolts, protected by special spring washers, detail of which appears in Fig. *c*. The joints allow a simple erection and adjust themselves automatically to all possible shrinkage. The joints can readily be unscrewed, and the roof dismantled, which is an obvious advantage for all temporary buildings.

The length of the lamellas may be from 4 to 12 ft., according to span and design. For the majority of roofs having from 40- to 100-ft. spans, the 8-ft. lengths are used.

The form of the arch for the roof depends on the purpose of the building. There are four principal shapes:

1. The flat segmental arch roof, the thrust of which is taken by tie-rods, as illustrated in Fig. *d*. This type is used mostly for garages, factories, car barns, hangars, and various kinds of industrial buildings. The rise of the arch varies from one-seventh to one-fifth of its span.

2. The segmental arch roof, the thrust of which is taken up by buttresses, concrete piers, or wooden bents, is shown in Fig. *e*. This type is especially adapted for use in warehouses and exhibition buildings. The rise is generally one-fifth to one-third of the span.

3. The Gothic arch is especially adapted for churches, residences, barns, and warehouses where goods such as grain, ore, etc., are stored in bulk. The lamella roof construction may start on the ground.

4. The broach or circular roof is used principally for exhibition buildings where a particular architectural design is desired.

Figure *f* shows the elevation of an end connection of a lamella roof, designed for Concordia College, Bronxville, New York.

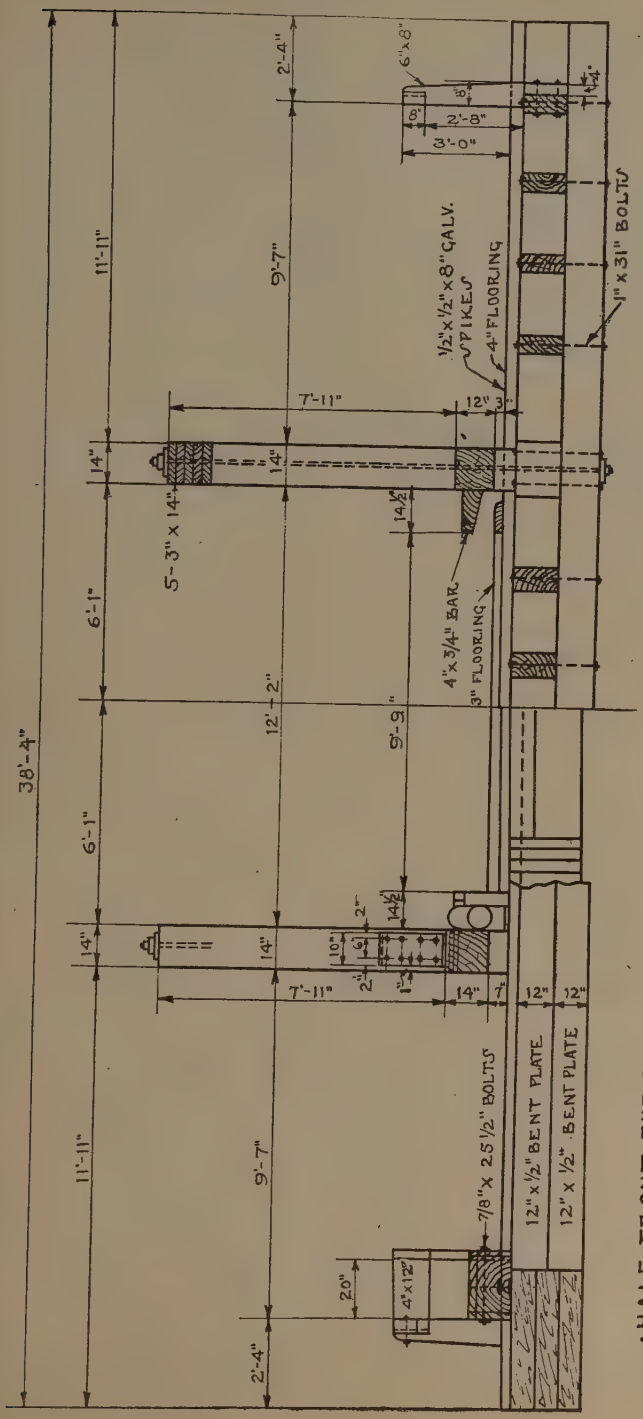
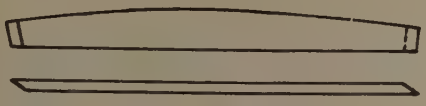
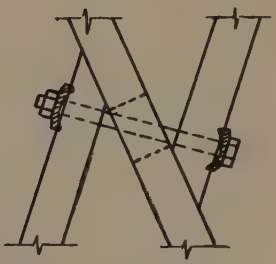


FIG. 139.—Half elevation and half-section through truss illustrated in Fig. 138.

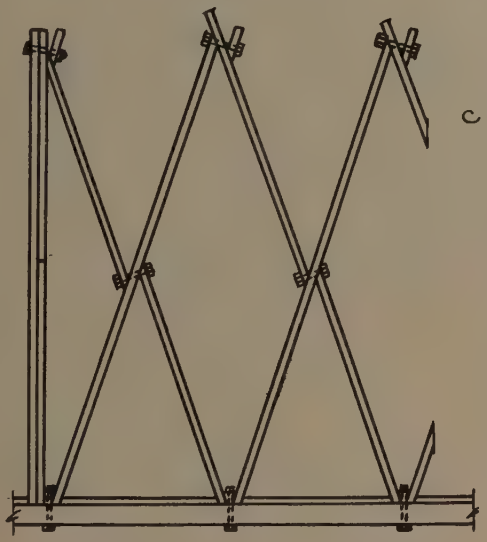
FIG. 140.—Bow string trusses, span 120 feet, designed for one-story garage by American Roof Truss Company.



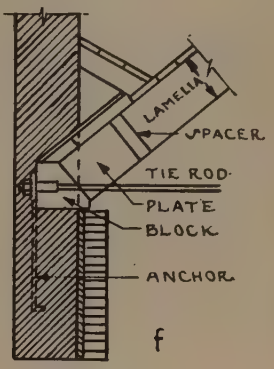
a A LAMELLA



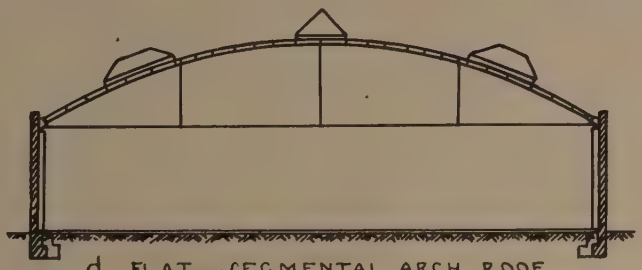
c DETAIL AT JOINT



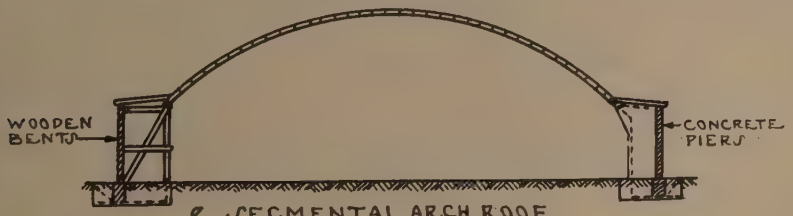
b DETAIL OF LAMELLA ROOF



f END CONNECTION



d FLAT SEGMENTAL ARCH ROOF



e SEGMENTAL ARCH ROOF

LAMELLA ROOF CONSTRUCTION

Plate 68.

The tie-rods for the 63-ft. span are supported by hangars, at one-third points, and are 19 ft. on centers along the building.

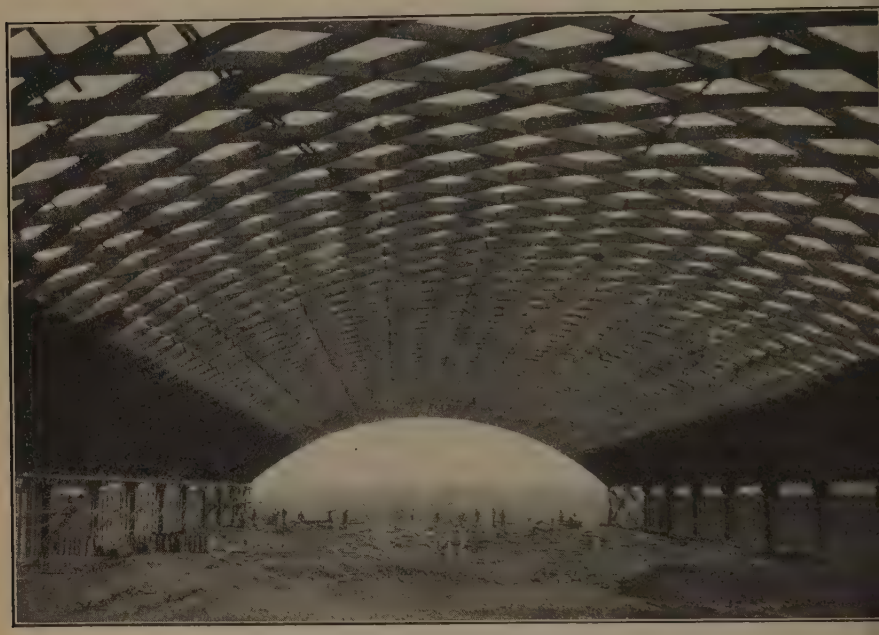


FIG. 141.—Lamella roof construction.

Figure 141 shows the roof of a riding academy at St. Louis, Missouri before sheathing and illustrates a type of lamella construction.

AIRPLANE HANGARS[1]

Careful investigation indicates that for hangar purposes the commercial type of bowstring roof truss built of southern pine, Douglas fir, or other structural lumber is most satisfactory and economical. These trusses are available from a number of companies which supply them complete and installed on the job at figures which usually compare favorably with the cost of local fabrication and erection by inexperienced carpenters.

Such trusses generally are not designed for large, concentrated loads such as result when planes are lifted by chain hoists; but, on account of the provision for snow and wind loads and the high safety factor of lumber for short-time loads, they can be used safely, in most instances, for such purposes, for loads up to 1 ton for the smaller trusses and 2 to 3 tons for the larger trusses. Hoists should be suspended from at least two well

[1] "Airplane Hanger Construction," Rev. Ed., December, 1928, National Lumber Manufacturers Association, Washington, D. C.

separated points where vertical web members intersect the lower chord of the truss.

These trusses may be obtained from local lumbermen, and it will be advisable for those building hangars to ascertain the cost of commercial trusses complete in place, as compared to that of trusses designed, fabricated, and installed by local contractors. Where roof trusses are designed locally, they should provide for a snow load of not less than 40 lb. per square foot in the northern states and an alternative live load of not less than 20 lb. per square foot, for wind pressure, in localities where snow loads are unlikely.

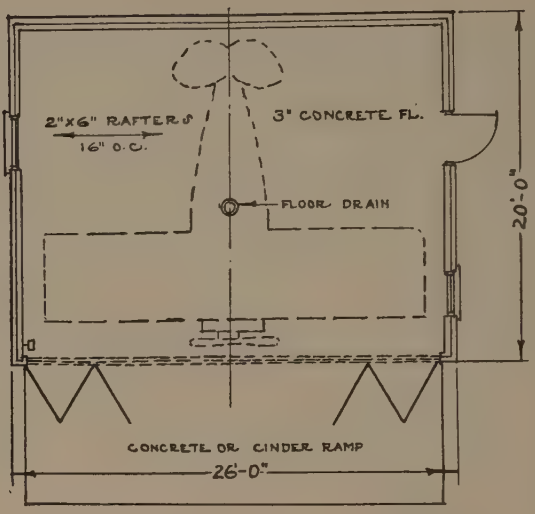
The new type of building construction previously described, and recently introduced into this country, known as the *lamella* or *non-plus* method of roof framing, should be highly adaptable for hangar purposes.

Drainage.—Care should be taken that the siding of lumber hangars does not come in contact with the soil at any point, and a separation of not less than 1 ft. is exceedingly desirable. The details in the drawings providing for a concrete curb around the walls on which the soleplate and studding rests should be carefully observed. Columns should be bolted into their foundations, and the concrete footings on which timber columns rest should be carried well above the floor to avoid dampness and possible decay of the column. The hangar floor level should be slightly above the level of the field and should be sloped (¼ in. per foot) toward the door.

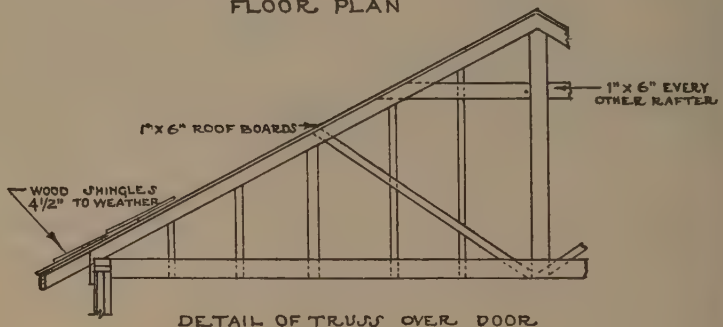
Single-plane Square-type Hangar.—This building is designed primarily for small ships and should prove adaptable and economical for private hangars and small fields. The over-all dimensions shown in *Plate* 69 apply only for the smallest planes and will need to be increased, with particular reference to door openings, in consideration of types of planes to be housed. A great majority of commercial single-seat and pleasure types range in wing spread from 24 to 40 ft. If the door opening of the square-type hangar is increased to more than 30 ft., it will be necessary to increase the size of truss members over the opening to 2 by in. and to splice the lower chord at the center. If the depth is increased to over 24 ft., three trusses similar in all respects to that shown over the doors in *Plate* 69 should be used, and purlins placed across them to carry the roof structure. In other respects, the building should be satisfactory for planes up to about 36-ft. wing spread.

The foundations may be of concrete, as shown in the plans, or, where the ground is uneven and it is desired to use a timber or cinder-fill floor, the structure may be supported on 10- or 12-in. posts embedded in the ground at suitable intervals.

The walls consist of 2- by 4-in. studs covered on the outside with a layer of good building paper and then with drop siding or matched sheathing. If desired, a single girt may be substituted halfway between



FLOOR PLAN



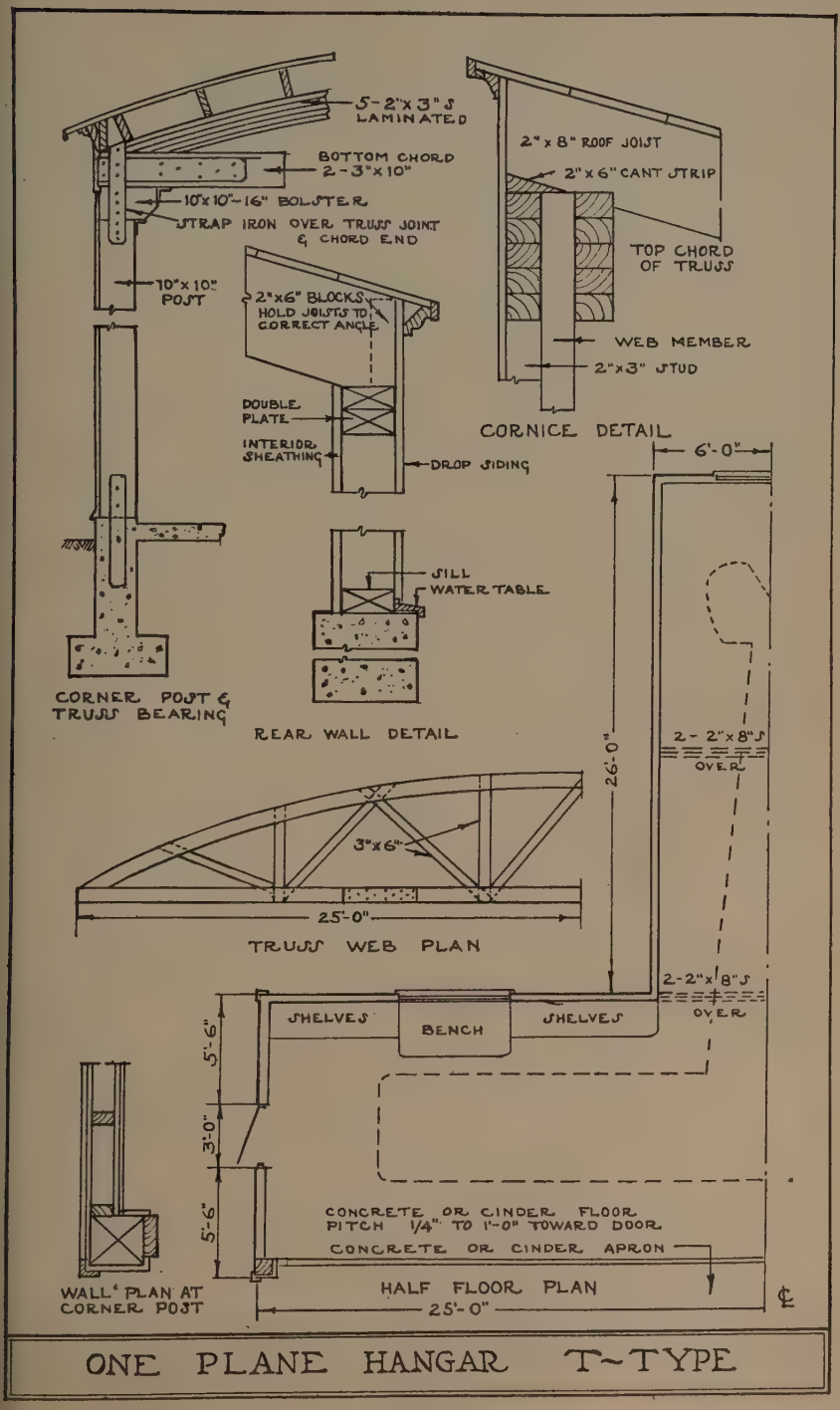
DETAIL OF TRUSS OVER DOOR

PLAN OF TRUSS OVER DOOR

FRONT ELEVATION SIDE ELEVATION

ONE PLANE HANGAR SQUARE TYPE

Plate 69.



ONE PLANE HANGAR T-TYPE

Plate 70.

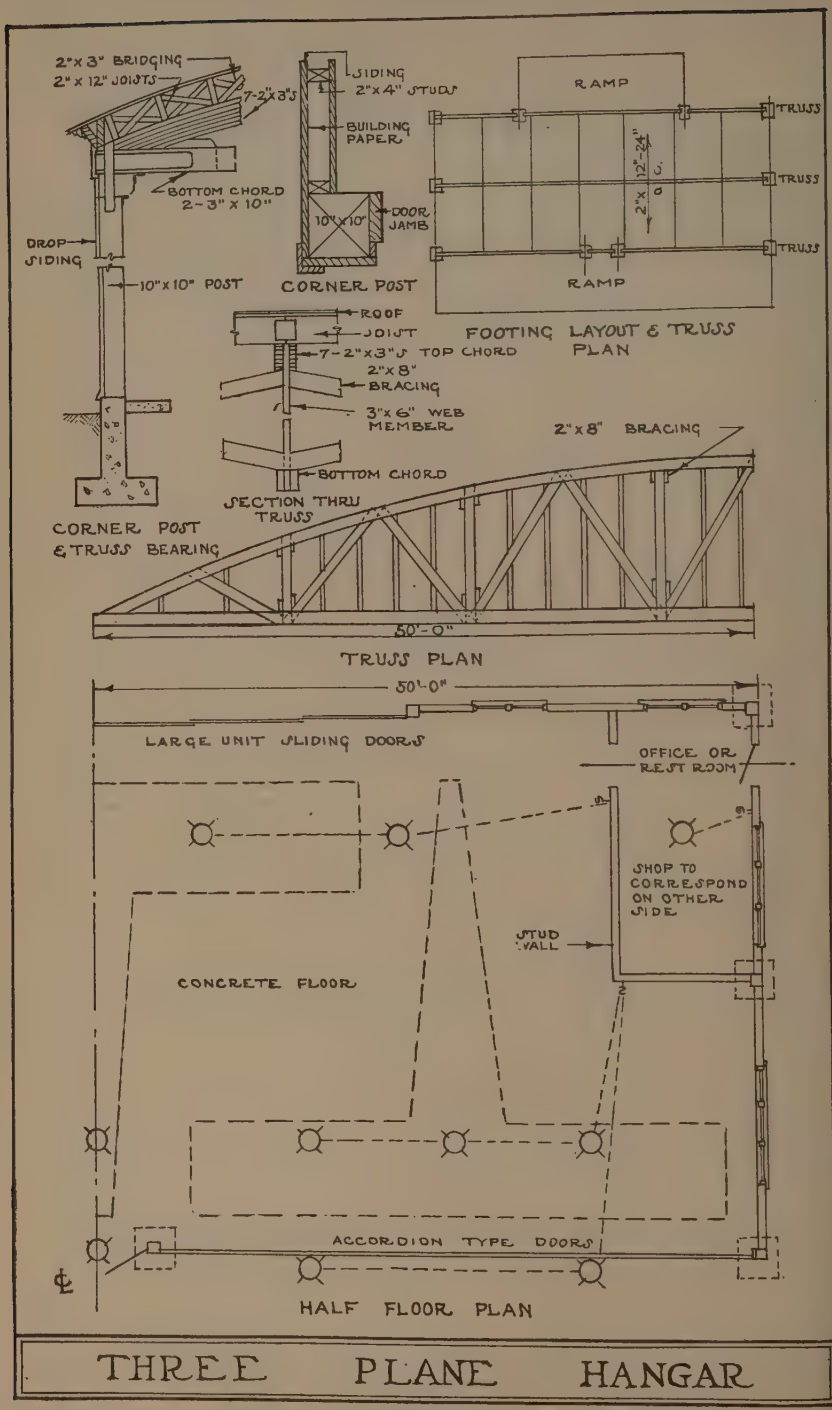

2"x3" BRIDGING
2"x12" JOISTS
7-2"x3"S
BOTTOM CHORD 2-3"x10"
DROP SIDING
10"x10" POST
SIDING
2"x4" STUDS
BUILDING PAPER
10"x10"
DOOR JAMB
CORNER POST
RAMP
TRUSS
TRUSS
TRUSS
12'-24" C.
2"x6"
RAMP
FOOTING LAYOUT & TRUSS PLAN
ROOF
JOIST
7-2"x3"S TOP CHORD
2"x8" BRACING
3"x6" WEB MEMBER
BOTTOM CHORD
SECTION THRU TRUSS
CORNER POST & TRUSS BEARING
2"x8" BRACING
50'-0"
TRUSS PLAN
50'-0"
LARGE UNIT SLIDING DOORS
OFFICE OR REST ROOM
SHOP TO CORRESPOND ON OTHER SIDE
STUD WALL
CONCRETE FLOOR
ACCORDION TYPE DOORS
HALF FLOOR PLAN
THREE PLANE HANGAR

Plate 71.

the sill and roof plate, and vertical board and batten siding may be employed. If this is done, the corners of the building should be braced in each direction, with knee braces strongly nailed or let into the material of the corner posts and plates. In fact, such bracing is desirable for all hangars exposed to high winds. Rafters should be 2 by 4 in., 16 in. on centers, or 2 by 6 in., 24 in. on centers, with roof boards of matched inch lumber. Where the climate is moderate or the building is not to be heated, material can be saved by using square-edge roof boards 1 to 2 in. apart, depending on their width and the nailing requirements for shingles.

Single Plane T-type Hangar.—For planes with a wing spread over 36 ft., the T-type hangar shown in *Plate* 70 probably will be more economical and satisfactory, requiring as it does the use of only one truss and no purlins for support of the roof area.

Foundations and roof and wall construction are similar to those for the square-type hangar. No provision has been made for housing and heating plant, but, if desired, this can be placed in an outside enclosure in one of the angles of the building. It should be completely enclosed inside with metal lath and plaster, and the chimney carried well up above the hangar roof to provide good draft.

For support over the door opening, one of the commercial types of timber trusses previously mentioned will be found most desirable. This can be bought through local lumberman.

The doors will need to be higher, and the hardware will be somewhat more expensive than for the smaller square-type hangar. The accordion type of door is often used for this building.

Three-plane Hangar.—Extra accommodations for not less than one plane are desirable at all fields for the housing of visiting planes. The three-plane type not only takes care of the ordinary small field equipment but also affords this desirable additional space for visitors.

The building shown on *Plate* 71 employs three 100-ft. commercial timber trusses running lengthwise. The front and back trusses are supported midway to provide suitable door openings, and the hangar is designed to be used from either side. The center truss is carried clear across the building without inconvenient posts or piers in the floor space. The door openings on opposite sides facilitate removal of any one plane without disturbing others.

BRIDGES AND TRESTLES[1]

In bridge building, as in other construction, safety and stability of the structure depend largely upon the nature of the underlying foundation. Where soil conditions do not offer sufficient bearing for the load to be superimposed, timber piling is used to insure stability and solidity of base.

[1] *Reports* of Committee on Wooden Bridges and Trestles, American Railway Engineering Association, Chicago, Illinois.

The bearing power of the soil may be determined by an examination of the materials of which it is composed, by borings, by test piles that are driven, loaded, and then observed with care as to settlement, or by other means.

Pile Testing.—Where piles depend mainly on skin friction or friction along the surface of the pile, for bearing value, they usually develop a much greater bearing value ½ hour or more after they are driven than immediately thereafter. Hence, before the "test piling" is really tested, it is advisable to wait until 24 hours after the driving, when a right determination of bearing value can be more safely made.

Formula.—It is safe to say that there is no formula or rule that can be blindly relied on for ascertaining the bearing power of piles. The formula known as the *Engineering News formula* is given below as being the one which has afforded more satisfaction than any other, but it should be noted that results from its use are sometimes wholly misleading. In fact, all rules and formulae should be modified, in so far as it is possible, by experience and judgment and as much test data as can be acquired, if the best results are to be obtained.

$$\text{For drop hammers, } P = \frac{2Wh}{S+1}$$

$$\text{For steam hammers, } P = \frac{2Wh}{S+0.1}$$

P indicates safe load in tons; W is weight of hammers in tons; h is the height of the fall, in feet; and S is the penetration in inches under the last blow, or the average of the last five blows.

In their latest manual, published in 1921, the American Railway Engineering Association recommends for trestle piles an average penetration of ½ in. under the last five blows of a 3,000-lb. hammer falling 15 ft., which is the equivalent of a safe load of 30 tons, if values are substituted in the above formula.

Ways of Driving.—Piles may be driven by the use of a water jet, a steam hammer, or a drop hammer. The use of the water jet is preferable where the soil is sandy, but a hammer should be used to test the final degree of penetration and thus estimate the bearing power.

If piling is to be driven where the soil is of a hard, gravelly nature, the water jet may still be used, if a sufficiently powerful volume of water and pressure are available. This method of driving has the definite advantage of not injuring the piling by overdriving, and even when conditions prevent its being used as the principal factor, it can always be of use to assist in the driving. Of the other two methods, the steam hammer is considered less likely to injure wooden piling than the drop hammer.

If, during the driving of piles, the hammer shows a tendency to bounce, or if the butt of the piles shows signs of brooming, or if at any time the pile seems to stagger under the impact of the hammer, it should be assumed at once that the pile has been driven to refusal.

In ordinary soils, piles drive better and with less danger from splitting, if no metal shoes are used and if the tips are cut square. Shoes ought to be used, however, in hard driving through gravel, shale, hard clay, etc. Caps will help in distributing a load over the head of a pile and thus lessen the tendency to broom.

Wooden Trestles.—A great advantage in using wooden trestles lies in the economy with which they can be constructed.

It has been demonstrated by repeated estimates that a first-class timber trestle can be erected, maintained, and replaced every 15 years—this being the estimated life of such a structure—for less than the interest on the investment required to build a so-called *permanent* structure of the same kind.

Where soil conditions are unsuitable for post or column pedestals because of frost action, railroads commonly drive pile bents, as giving a more stable foundation. And even for low trestles, piles are used whenever it is possible, in preference to using framed bents with mud sills. In fact, piles are preferable under all conditions where a penetration of 3 ft. or more can be obtained.

The Committee on Wooden Bridges and Trestles of the American Railway Engineering Association, in a report made in 1926, indicates that when treated timber is used in their construction, 30 years rather than 15 is a fair average for the life of these structures. This committee recommends treated timber for trestles in all permanent work.

Pile trestles are limited by the length of the piles and are seldom more than 30 ft. from the base of a rail to the ground or water surface. They are usually considerably less than 30 ft. high.

The greater the number and length of piles to be driven the cheaper the rate per foot per pile at which they can be driven. It is more expensive, therefore, to build short stretches of pile trestles at considerable distances apart than to assemble more piling at lesser distances.

Some Details of Construction.—Figure 142 shows the elevation of pile bents 20 ft. or less in height, used on a Western line. For cut-offs on piles, all timber surfaces in contact, ends of stringers, and bolt holes should be treated in the field with hot preservative.

Bolt threads outside of nuts should be coated with thick red-lead paste.

Stringer chord bolts may be placed with nuts between or outside stringer chords.

All unused holes should be filled by driving creosoted plugs to bottom of hole.

All holes for drift bolts should be bored $\frac{1}{16}$ in. less in diameter than the drift bolt.

All holes for bolts should be bored $\frac{1}{16}$ in. larger in diameter than bolt. Holes for lag screws should be bored $\frac{1}{16}$ in. less than diameter of screw through guard rail and $\frac{1}{4}$ in. less than diameter of screw into tie.

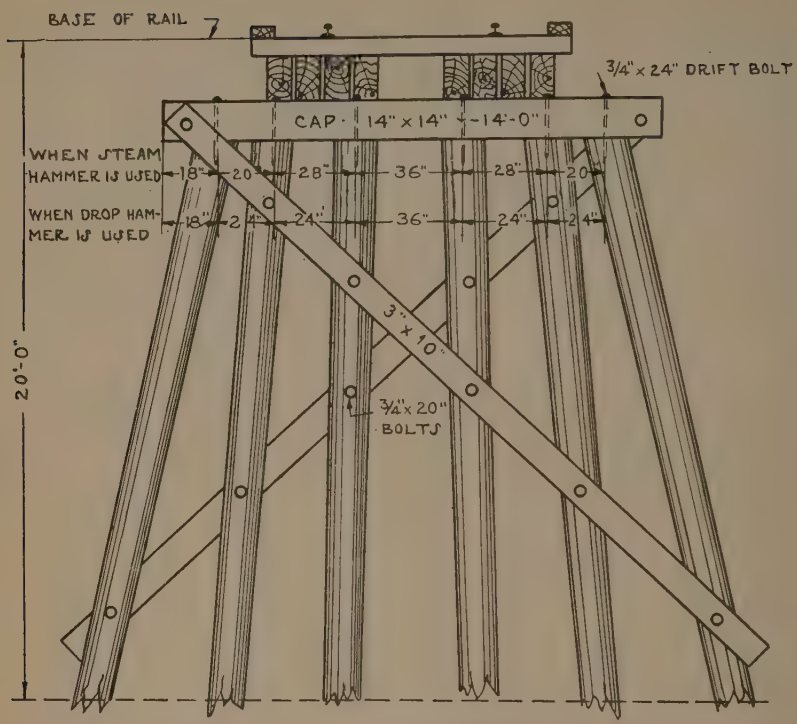

BASE OF RAIL
3/4" x 24" DRIFT BOLT
CAP · 14" x 14" · -14'-0"
WHEN STEAM HAMMER IS USED
18" 20" 28" 36" 28" 20"
WHEN DROP HAMMER IS USED
18" 24" 24" 36" 24" 24"
20'-0"
3" x 10"
3/4" x 20" BOLTS

FIG. 142.—Pile trestle bent 20 ft. and less in height, Missouri Pacific Lines.

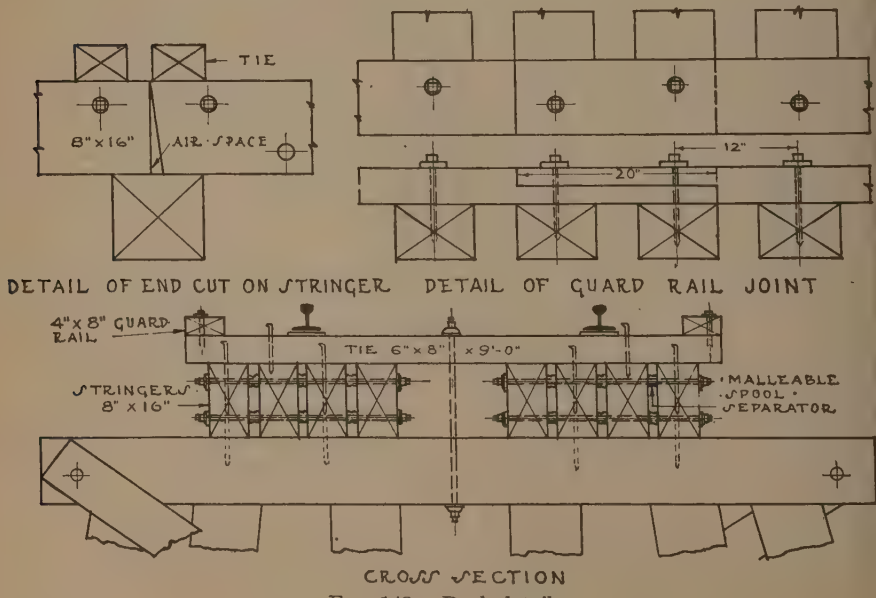


FIG. 143.—Deck detail.

Figure 143 shows some of the deck details on standard pile and frame trestles. In this case, lag screws are used, in order that the ties may not be dapped into the stringers or guard rail over the ties. It should be remembered that a proper installation of the lag screws is always essential, which means that they must be screwed in and not driven.

Plate 72 shows a standard frame trestle with footing details for mud sills and pedestals; regular pile-capped bents; and longitudinal bracing for alternate spans. Similar details are used for pile bents, except that the piles run up to a cap supporting the stringer, to replace the 12- by 12-in. posts.

On open deck trestles, it is good practice to protect the stringers and caps from hot cinders by putting galvanized sheet iron over these pieces and bending it down about 6 in. on the sides. This also serves as protection from moisture. Covering the ties, however, prevents inspection for decay and is not recommended.

Plate 73 shows details of bents for ballast deck trestles on a western railway. For all such trestles, creosoted timbers are recommended.

On high trestles, especially, the matter of thorough bracing is of great importance. All braces should be well bolted at the ends, and as the appearance of a trestle adds to or detracts from the scenic beauty of a railroad, all timbers should be trimmed, and ragged edges smoothed. In sway and sash bracing, between the brace and the pile, fillers should be used, if needed.

Trestle Designs.—Different railroads adopt different designs for trestles, and these designs vary greatly in their economical value.

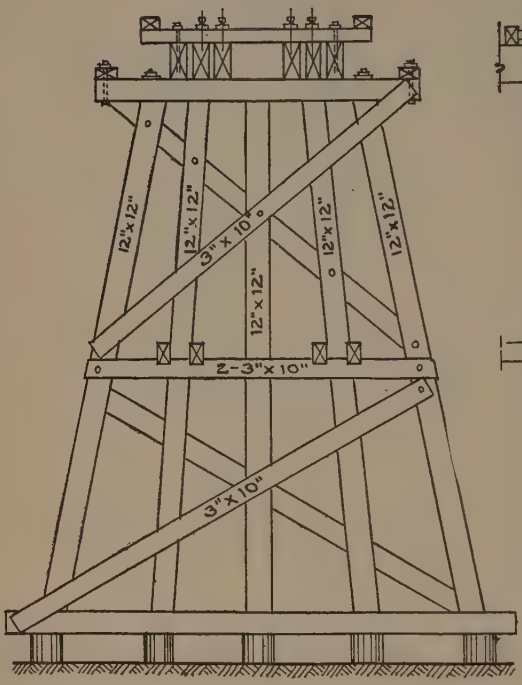
Comparison of the designs of 25 first-class roads shows great difference under apparently similar conditions. Most roads use dense southern pine or Douglas fir for stringers. But for the same class of loading, one road uses three 10 in. by 18 in. on a 14-ft. span, while another road uses the same on a 15 ft. 9 in. span. And one road may use a five-pile bent as standard, while another road uses a six-pile bent.

These differences are probably due to assumed unit stresses and, perhaps, at times, to designing for future loadings.

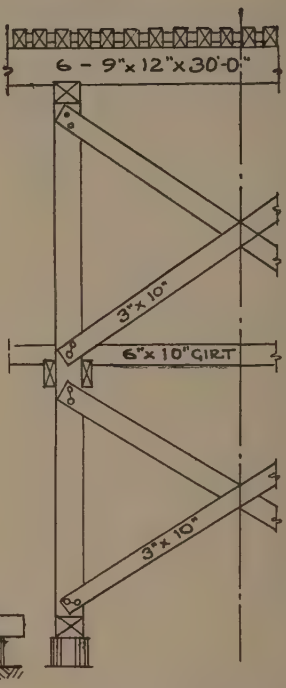
Variation in spans of panels is usual, running from 10 to 16 ft. in different roads, while stringers vary from two to six under one rail, depending on the loads to be carried. The number of piles per bent varies from four to six.

One railroad specified dense southern pine, good for 1,750 lb. per square inch in bending, and then designed for 1,200 lb. per square inch, which is the unit stress allowable in common-grade lumber.

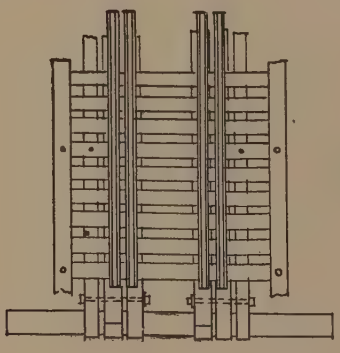
Another point on which there seems to be a difference of opinion is as to whether stringers with sapwood should be placed with the sapwood on top or underneath.



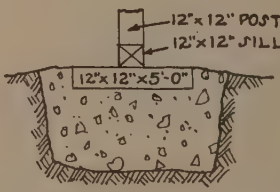
TYPICAL FIVE POST BENT 19'-0" TO 30'-0"



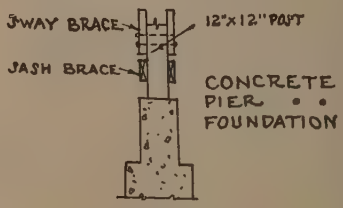
HALF ELEVATION



PLAN

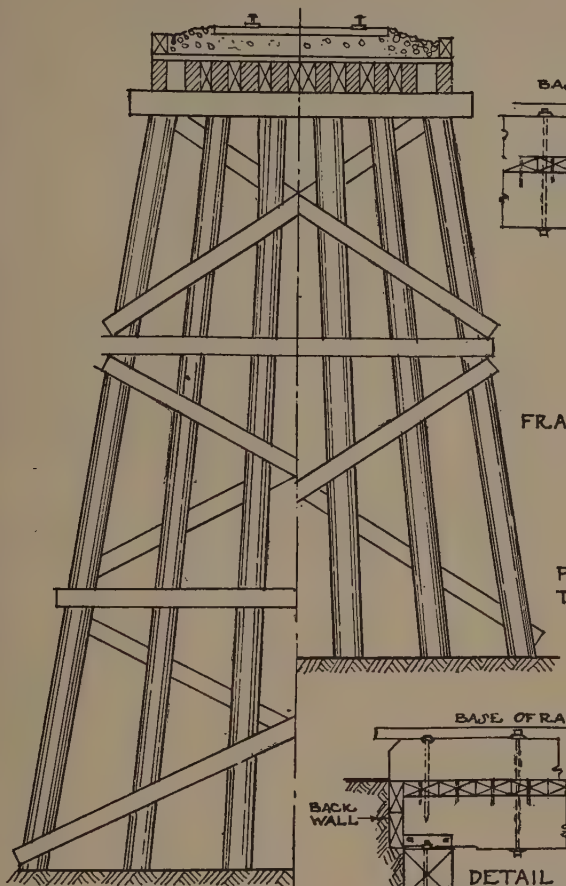


BROKEN STONE FOUNDATION



STANDARD FRAME TRESTLE

Plate 72.


BASE OF RAIL
FRAMING OVER BENT
PILE BENT 22'-0" TO 30'-0" HIGH
BASE OF RAIL
BACK WALL
DETAIL AT END
PILE BENT 31'-40' HIGH
6" X 8" X 8'-0" TRACK TIE
14" X 14" X 16'-0"
CROSS SECTION OF DECK

BENTS FOR BALLAST DECK TRESTLE

Plate 73.

The latest manual of the American Railway Engineering Association recommends placing sapwood down, a recommendation based on the discussion at a convention held in 1907, when the specifications were originally adopted.

At that convention the argument against placing the sapwood up was that the danger from hot coals and from exposure to moisture was increased.

Those who were against this point of view argued that with the sapwood down, the bearing value of the stringer over the cap would be reduced. Since sapwood, however, is as strong as heartwood, any decrease in bearing value would result from decay of the sapwood at the bearing point. It was pointed out that the sizing of the stringers over the caps would usually remove such sapwood as existed and thus give a bearing on the heartwood.

Of course, if galvanized-iron sheeting should be placed over the stringers, the arguments as to fire hazard and effects of moisture would be invalidated, and the sapwood could be placed on the upper side. Without such protection, however, it is recommended that the sapwood be placed downward.

Figure 144 shows the section of a typical timber trestle of the Texas State Highway Department. The half section shows stringers lapping over the bent. This was designed for a 10-ton truck live load, where there is no impact. Southern pine was specified, and all timbers and piling are treated. Part of the specification reads:

The tops of foundation piles shall be embedded in the concrete footing at least 1 ft., and where seals of concrete deposited in water are used with piles, the piles shall project at least 1 ft. above the top of the seal concrete. They shall be cut off level, at such elevation that the tops of the piles will always be wet.

Foundation piles for framed bents shall be cut off level approximately 3- ft. above the surface of the ground, and the cap rigidly secured to each pile by drift bolts extending at least 9 in. into the pile.

Trestle piles shall be cut off level at the elevation shown on the plans, and the caps secured as described above. If the cut-off is 10 ft. or more above the ground line, timber piles shall be braced by diagonal cross-bracing composed of 3 by 10-in. timbers, secured to the piles by ¾-in. diameter bolts.

In bents of untreated piles the heads of the piles shall be thoroughly coated with a thick protective coat of red-lead paint, hot tar, tar asphaltum, or hot coal-tar cresote before the caps are placed.

The tops of all piling shall be sawed to a true plane as shown on the plans, and at the elevation fixed by the engineer. Piles which support timber caps or grillage work shall be sawed to the exact plane of the superimposed structure and shall exactly fit it. Broken, split, or misplaced piles shall be drawn and properly replaced. Piles driven below the cut-off grade fixed by the engineer shall be withdrawn and replaced by new and, if necessary, longer piles, at the expense of the contractor.

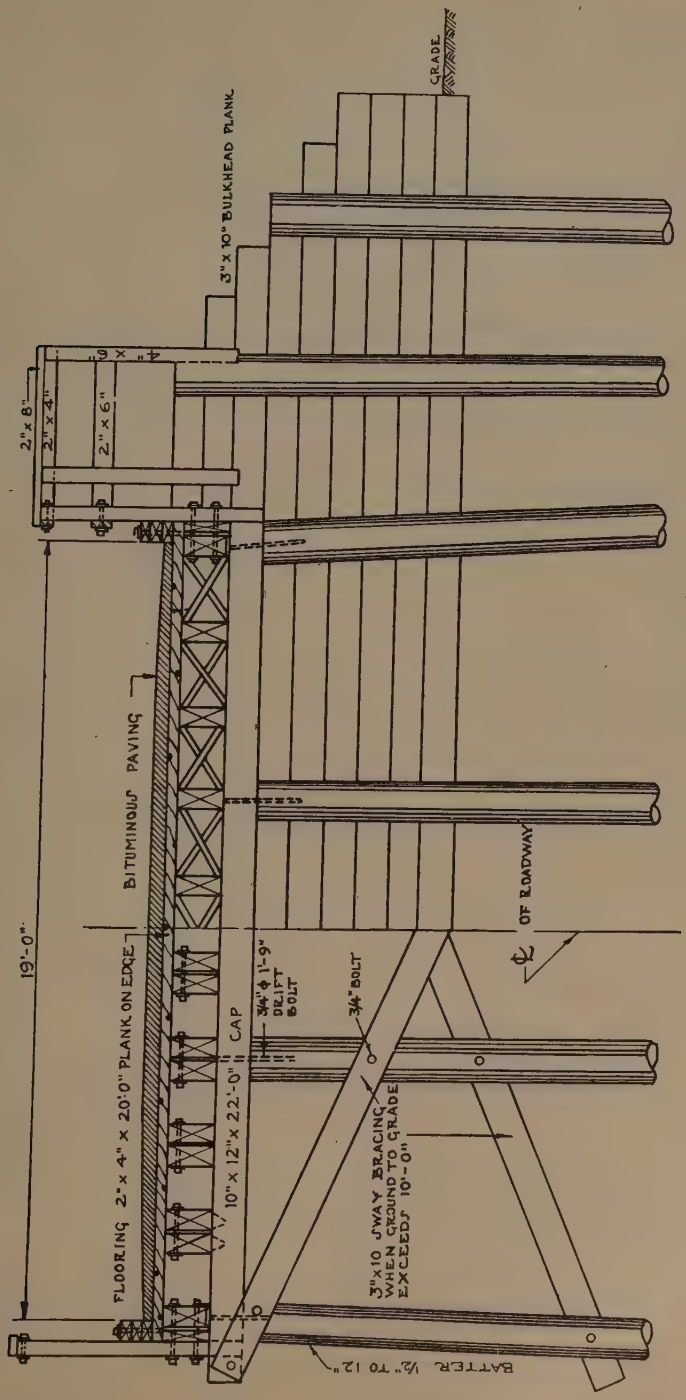

GRADE
3" x 10" BULKHEAD PLANK
4" x 6"
2" x 6"
2" x 4"
2" x 8"
BITUMINOUS PAVING
19'-0"
FLOORING 2" x 4" x 20'-0" PLANK ON EDGE
10" x 12" x 22'-0" CAP
¾" ϕ 1'-9" DRIFT BOLT
¾" BOLT
OF ROADWAY
3" x 10" DIAGONAL BRACING WHEN GROUND TO GRADE EXCEEDS 10'-0"
BATTER ½" TO 12"

Fig. 144.—Section of timber trestle.

The specifications also require that the piles have a 12-ton bearing, as computed by the *Engineering News formula*, given on page 502.

Figure 145 shows standard trestle construction on a trolley line in New Jersey, operated by the Public Service Railway Company. The chestnut poles for the trolley wires are carried on two 3 by 12 in., bolted to two piles and cantilevered out about 3 ft. to take the pole. The poles are also tied against the ends of the caps with wrought-iron straps ½ by 2 in., as indicated.

USE OF PILES IN BULKHEADS AND WHARVES

The choice of wooden piles for use along ocean waterfronts should be influenced by whether or not borers are present; if present, only treated piles should be used. Usually, northern waters are comparatively free from marine borers; and so are waters full of sewage. Where wooden piles are constantly submerged, they are practically immune from decay; this is also true up to mean tide level.

In "Ports and Terminal Facilities,"[1] in a discussion of wharves, it is stated that "pile construction has several advantages other than simple cheapness."

1. A pile structure does not materially reduce the tidal prism. That is, it does not affect materially the amount of water which flows through its channels into and out of the harbor with the changes of tide.

2. Pile wharves are more elastic. The kinetic energy of a ship moving at a speed of 1 mile an hour or 1½ ft. per second is 350 ft.-tons, and twice this speed 1,500 ft.-tons. This energy must be absorbed in some manner, or it acts as a destructive force of that amount to both pier and ship. Ships will shun a wharf that puts all the destructive force of impact on the ship. An elastic pile structure absorbs this energy. With other kinds of solid structure fenders must be provided, such as buffers made of faggots, rope, or timber and springs.

Pier Construction in New York Harbor.—In the *Transactions* of the American Society of Civil Engineers, of December, 1914 (p. 506), the following statement is made:

The wooden pier, consisting of a timber deck and floor system supported by timber piles, became the adopted type. It was cheap, durable, and readily adaptable to all classes of shipping. One of the most important characteristics of piers of this type is the ease and economy with which it may be removed entirely, reconstructed wholly or in part, or expanded at a low cost, to meet the increasing needs of commerce and shipping. A dock or system of docks sufficient to accommodate the shipping at the time it was built might be found to be inadequate and obsolete within a comparatively short term of years, a complete rearrangement being then necessary.

With timber structures this transformation or reconstruction is a simple, rapid, and economical undertaking; it is difficult and costly with other kinds of structures.

[1] MacElwee, R. S., McGraw-Hill Book Company, Inc., 2d ed.

Later on is brought out the advisability of using reinforced concrete deckings in place of timber deckings, the claim being that thus considerable maintenance expense might be avoided. Subsequent discussions of this paper seemed to show, however, that the rigidity of a concrete deck

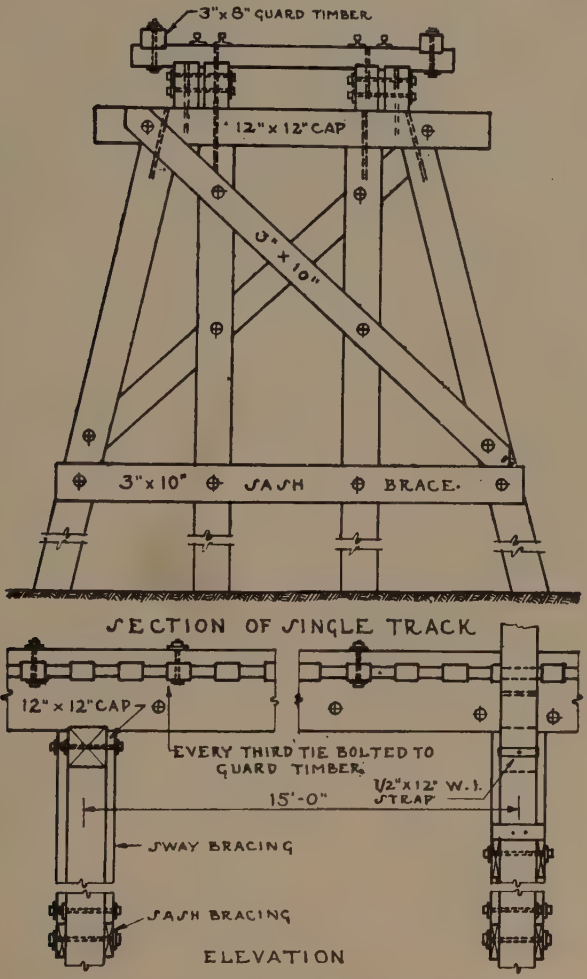


FIG. 145.—Standard trestle construction on a trolley line.

might prove a serious disadvantage in a pier where heavy shipping might dock.

The spacing of piles depends primarily on superstructure loading. Where pile clusters are driven to carry heavy loads, the fact that a limit exists as to the number of piles which can be crowded into a given area should be borne in mind; otherwise, the bearing power of the soil under the cluster may be exceeded, and the entire cluster may settle.

Piles should always be well braced, whether they are in or out of the water. In water, that part of the piling extending from the bottom to the surface of the water is unsupported column and for security requires strong bracing above the water. The safe load for unsupported piles is as follows:

$$P = S\left(1 - \frac{l}{60d}\right).$$

where P = safe load in pounds
S = allowable unit compression strength of timber in direction of grain,
l = unsupported length in inches, and
d = diameter of pile in inches at halfway point of unsupported length.

When treated piles are being placed, they should be handled with care in order to avoid cutting the surface and so destroying the effect of treatment; cant hooks and other such implements as might break the surface should be carefully avoided.

Pile specifications usually call for a uniform taper, the pile to be so straight that a line drawn through the center of the butt and tip will not fall outside the pile. With a minimum tip size of from 5 to 6 in., the butt may range up to 20 in. or even more in diameter, depending on desired length.

When the Erie Railroad Company constructed pier 9 at Weehawken, over the Holland vehicular tunnel, the specifications required that all piles should be driven with metal shoes and that the butts should have wrought-iron bands for protection.

Figure 146 shows the plan and cross-section of a three-bank ferry rack in New York City, at the Barclay Street terminal of the Delaware, Lackawanna and Western Railroad Company. It is specified that all timber higher than a line 4½ ft. above mean low tide is to be creosoted. Below that line timber will be constantly saturated and, therefore, not subject to decay. This ferry rack is severely tested by the heavy traffic, where ferries frequently strike against it and are guided into their slip by the rack.

Figure 147 is part of a cross-section of a typical bent in wharf and timber shed construction at Corpus Christi, Texas. The wharf extends 1,216 ft. along the harbor; 24 ft. back from the United States harbor line is a transfer shed 160 ft. wide, extending along the wharf. Approximately 90 of the 160 ft. of width is supported on piles, as shown in the figure. The remaining 70 ft. of the wharf rests on a dredged fill and levee and has an 8-in. shell flooring with a 2-in. asphalt top coat. A railroad spur runs along the inside building line of the wharf for convenient loading. The piles are all of dense southern pine. Concrete fire walls on piling divide the shed into four sections, each 304 ft. long.

Figure 148 shows part of a longitudinal section of the same wharf, through one of the fire walls. Note that the piles extend 9 in. into the

concrete footing. The minimum distance that a wooden pile should extend into a concrete footing of this type is 4 in., but 6 to 9 in. is better construction.

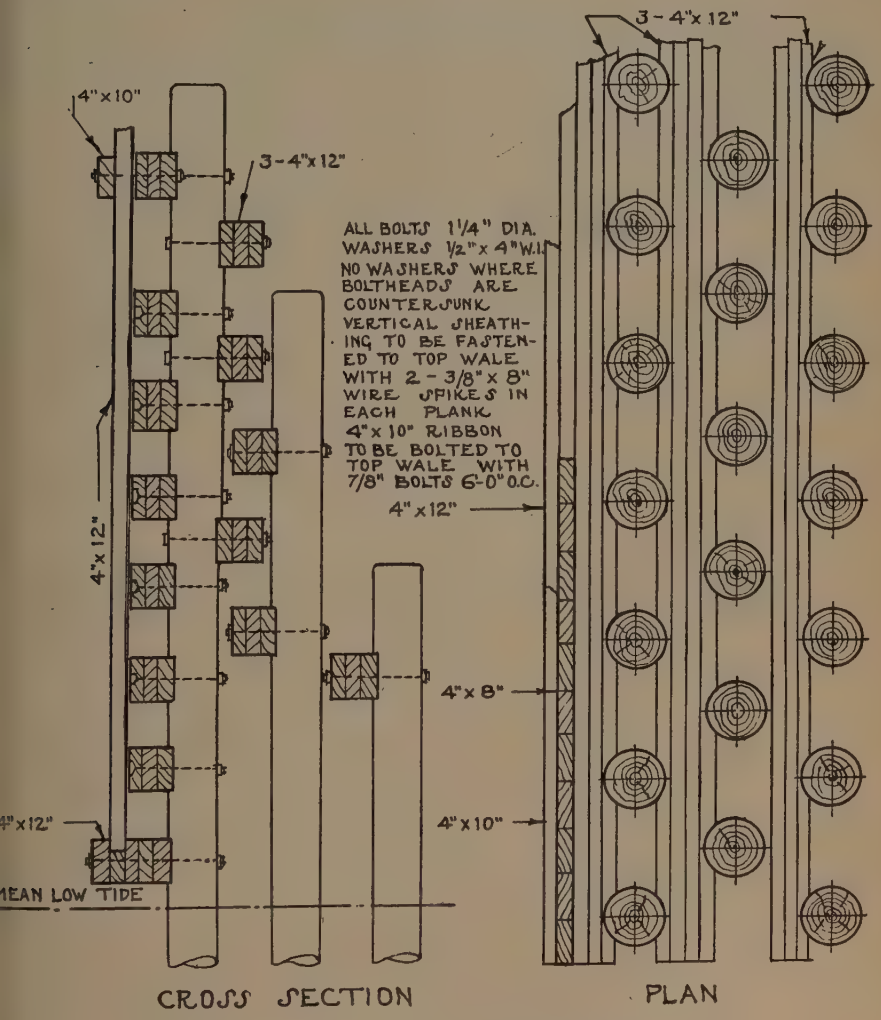


Fig. 146.—Plan and cross-section of a three-bank ferry rack.

Commonwealth Pier 5, South Boston.—Commonwealth Pier 5, which s 1,200 ft. long and 400 ft. wide, was constructed with a central core of olid fill, retained by granite walls on pile foundations, with an outside leck platform about 50 ft. wide on wooden piles. The piles under the granite wall are of spruce, and a timber-bed platform was constructed ying the heads of these piles together at about 1 ft. above mean low water, s a foundation for the granite sea wall. The deck platform piles are of

white or red oak with southern-pine girder caps and bracing for supporting a concrete deck.

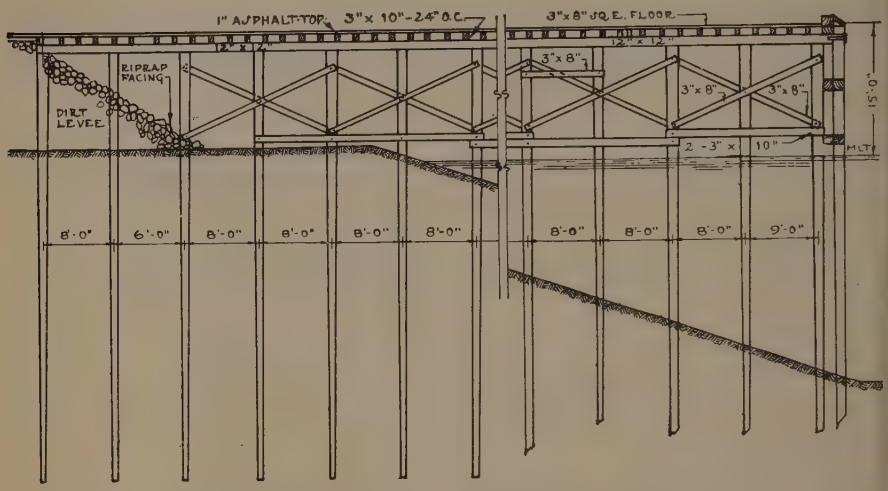


FIG. 147.—Cross-section of bent in wharf and timber shed construction at Corpus Christi.

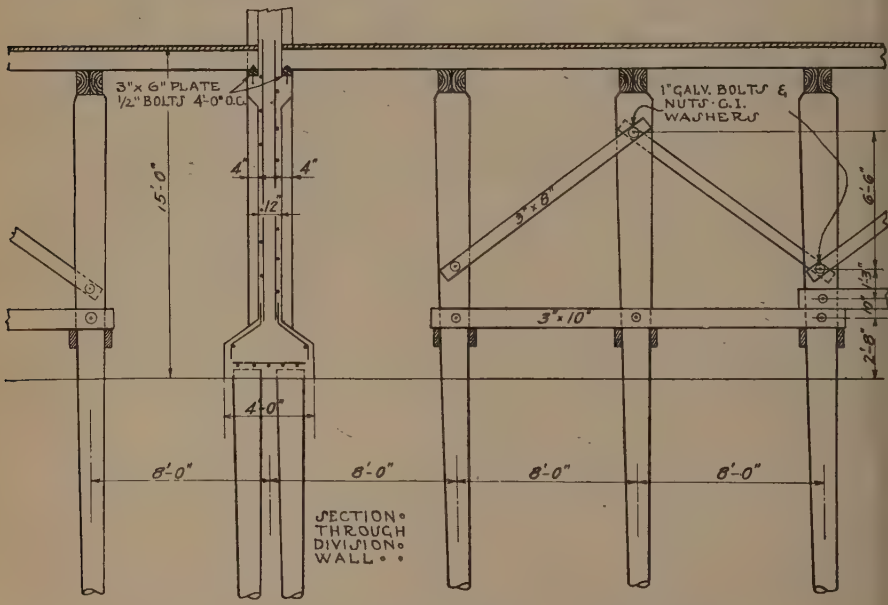


FIG. 148.—Part of longitudinal section of Corpus Christi wharf.

Commonwealth Pier 1, East Boston, is 150 ft. wide by 560 ft. long, constructed on wooden piles, and timber was used for both substructure and superstructure, including the floors.

Figure 149 shows part of a typical cross-section through water side of the pier and shed. Note the method of fastening the batter piles to vertical piles.

The specifications called for oak (either red or white) piles with southern-pine caps, stringers, flooring, and sheathing (all square-edge stock). Braces were rough oak; wall sheathing of cypress or spruce; window and door frames and sash of white pine.

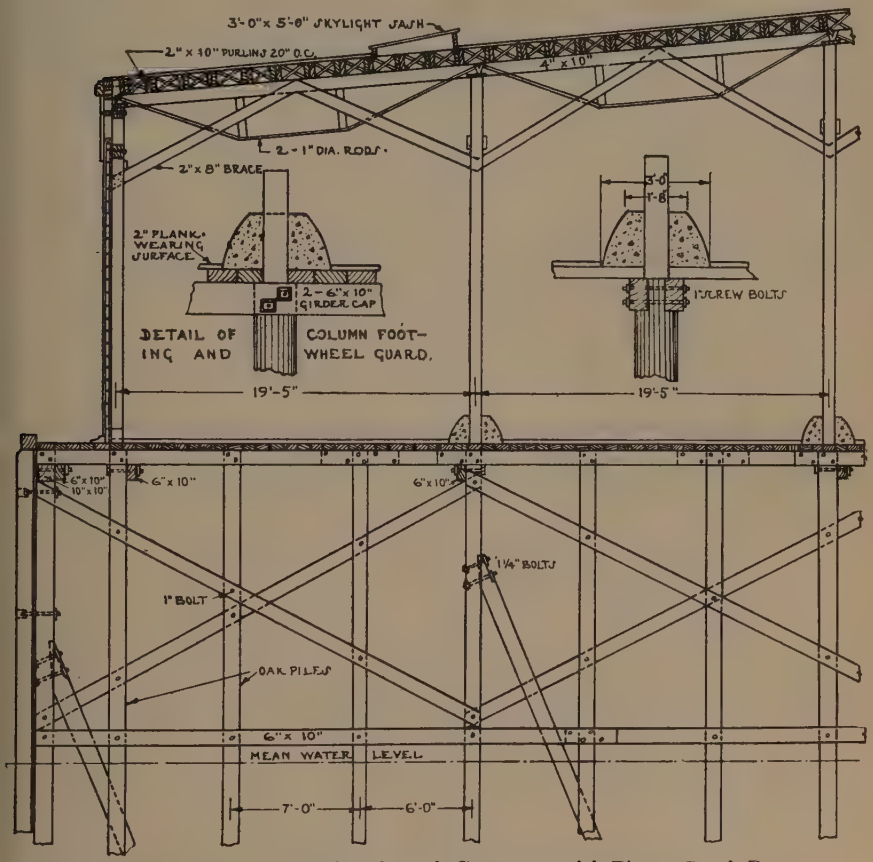


FIG. 149.—Typical cross-section through Commonwealth Pier at South Boston.

Over the 4-in. floor was placed 2 in. of hard-pine wearing surface, sized to even thickness. The subflooring is fastened with $\frac{3}{8}$- by 8-in. wrought-iron ship spikes, driven through bored holes. The 2-in. finished floor is secured by 20-d. cut spikes not more than 4 ft. apart.

Figure 150 shows a cornice detail of the previous figure and part of a combination roof truss.

Pier C, built by the Erie Railroad Company at Weehawken, is shown in Fig. 151. This pier is used for lighterage and is built of heavy timber

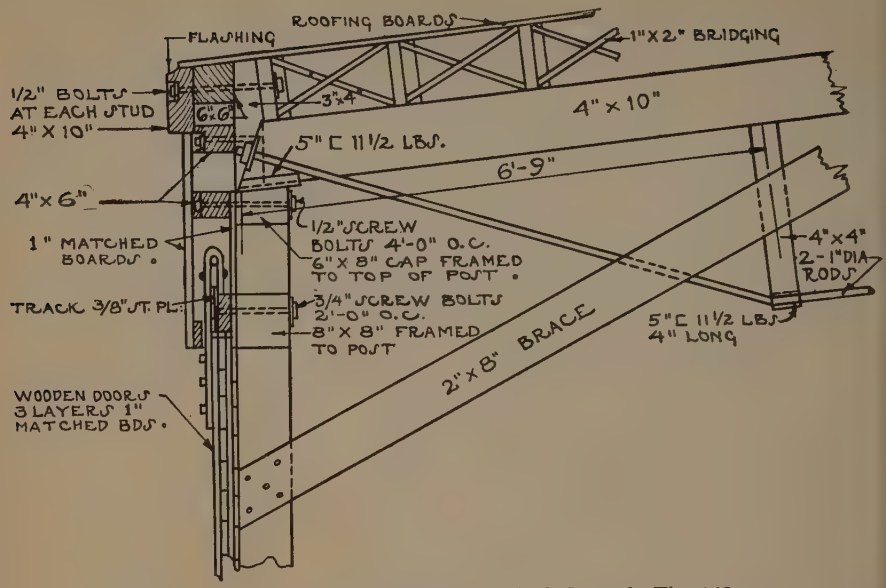


FIG. 150.—Cornice detail of pier and shed shown in Fig. 149.

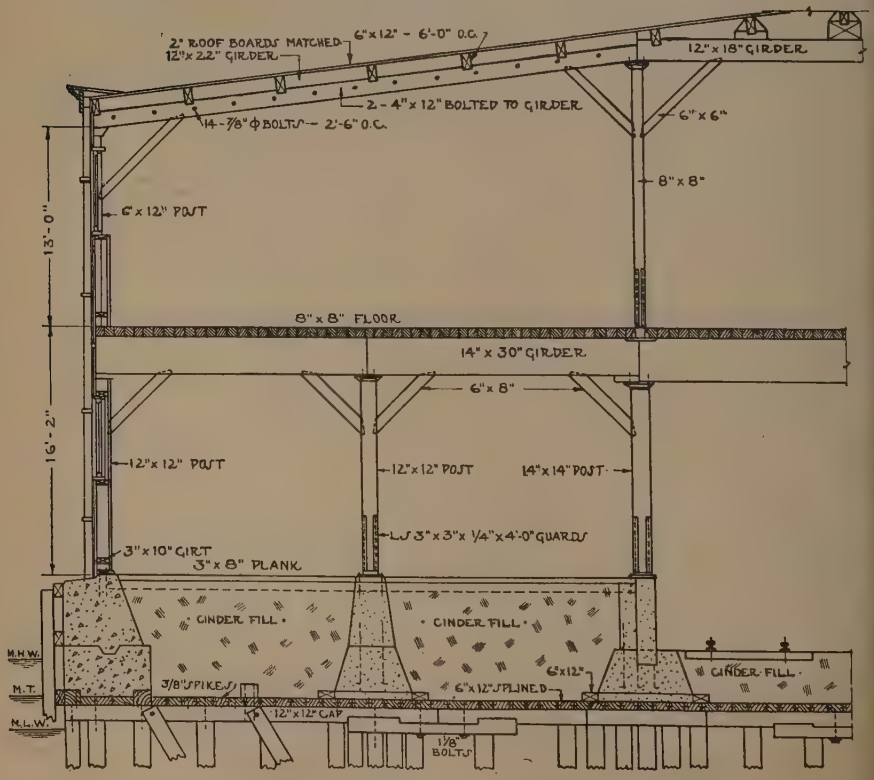


FIG. 151.—Section of pier built by Erie Railroad Company.

construction, to secure a slow-burning type of structure. A former pier that had been built with a steel superstructure was destroyed by fire. The present pier is approximately 830 ft. long by 100 ft. wide. A feature is the use of a cinder fill, retained by concrete walls on the outside, over

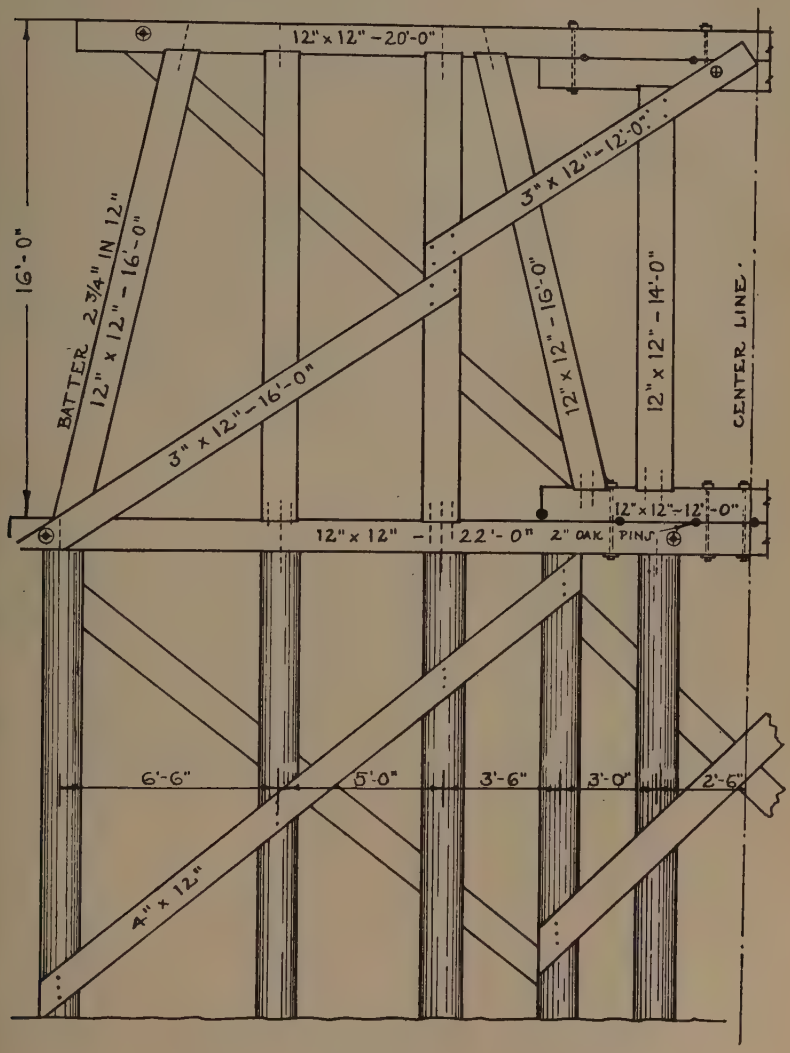


FIG. 152.—Section through bent of an ore dock.

wooden decking, which is intended to act as a fire stop to protect the substructure in case a fire should occur within the shed. Cinders were selected because no lighter material was available. The railroad company's experience has been that this decking and the pile caps under the cinders are low enough to be kept saturated and thus avoid decay. The

thought about the adopted design was that if another fire occurred, it might be controlled before the slow-burning-timber superstructure was destroyed but that if not, at least the floor system below the cinder fill would be undamaged, and, to quote one of the engineers, they could "sweep off the pier and go to work."

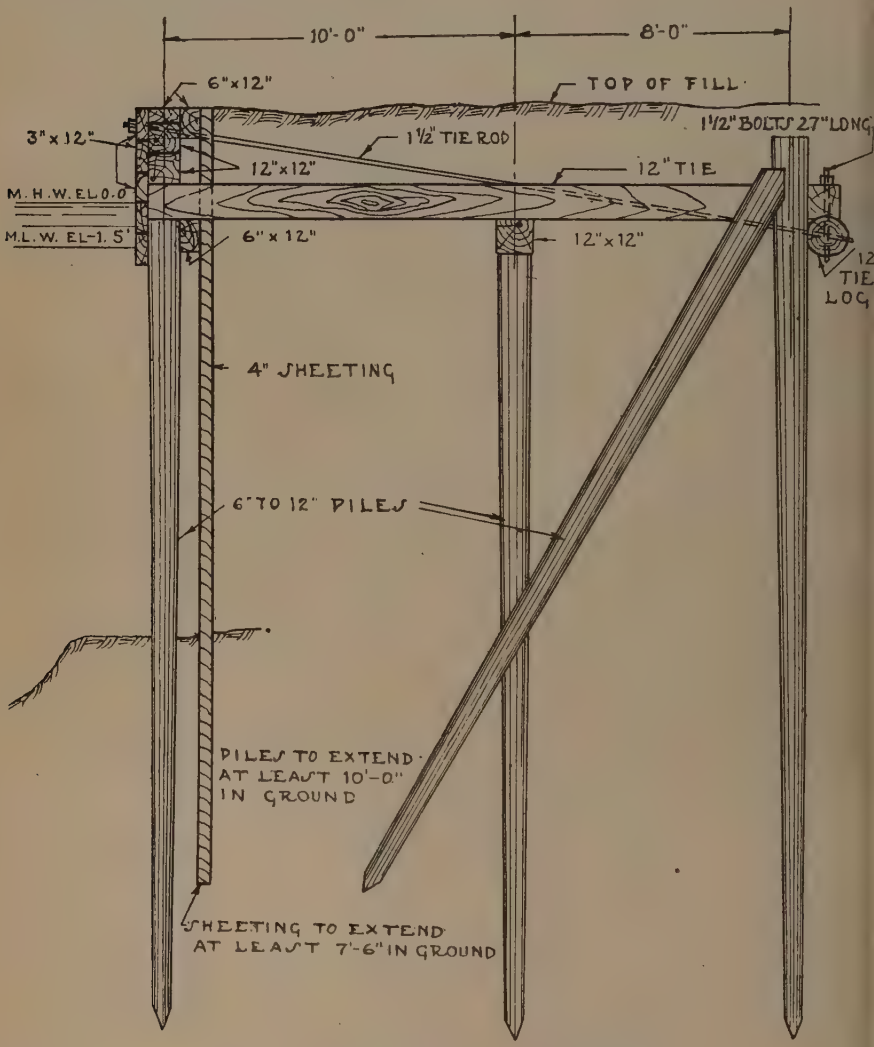


FIG. 153.—Bulkhead section at port of Baltimore.

The pier has one fire wall and is completely protected by a sprinkler system of the "dry" type. Approximately 445,000 lin. ft. of piling and 2,668,000 f.b.m. in substructure and superstructure were used.

A great many piles from the old pier were used, as an examination of a number of those which had been withdrawn disclosed no live teredos

and indicated that the slight negligible damage had occurred at least 18 or 20 years previous. There is no apparent damage being done by teredos or other borers in the vicinity of the Erie piers at the present time, although some damage was evidently done 20 years ago. The pier was designed for 500-lb. per square foot live load on the first floor, and 400 lb. on the second floor.

A section through one of the bents of an ore dock built by the Lake Superior and Ishpeming Railroad Company is shown in Fig. 152. The piles are capped, and the posts are dapped into the caps and dowelled.

FIG. 154.—First floor of wharf.

Figure 153 shows a bulkhead section belonging to the Bethlehem Steel Company and built under authority of the Baltimore Bureau of Harbors, Department of Public Works.

A statement from the harbor engineer is as follows:

I might mention that for this particular port, where we are not troubled with marine borers of any kind, timber construction is much more satisfactory than the concrete construction below a point about 18 in. above mean low water. The normal tide range at this place is 1.2 ft.

Figure 154 is a photograph of the first floor of a wharf built by the Port of Seattle Commission.

Figure 155, which shows the second floor, portrays clearly notched joints of the diagonals and the monitor roof and louvres. Note the method of providing a bearing for the steel floor girders by resting them

on the 6- by 10-in. posts, bolted, and keyed to 10- by 10-in. columns with 2-in. galvanized-iron pipe keys. A nailing strip 2 by 12 in., is placed on the steel girder to receive the 6- by 14-in. stringers.

FIG. 155.—Second floor of wharf.

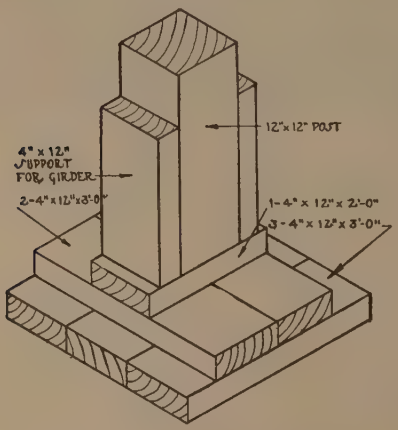


FIG. 156.—Footing detail.

Douglas fir is used throughout the structure except that West Coast hemlock was permitted for the wall sheathing. This was 1-in. ship-lap in widths of 10 in. or less, put on diagonally and nailed to each stud with at least two 8-d. nails.

The Louisville and Nashville Railroad, after excavating foundation for a large freight depot at New Orleans, spaced piles on 3-ft. centers under reinforced-concrete column footing, and after the piles were driven and cut off 1 ft. above the ground, 6 in. of sand was placed between the piles and thoroughly tamped. The concrete footings were then poured, and the piles embedded 6 in. in concrete. The sand was omitted only where good firm earth was encountered in the excavation.

Timber Footings.—Timber footings may be used, where they will be continually under water and where piles are not necessary. Footings usually consist of several courses of timber under the wall or post which is to be supported.

The lowest course is 2- up to 4-in. planking, laid close, to secure an even bearing. On this, at 90 deg., is laid the next course of planking or heavy timbers, their size depending on the load to be carried. The bearing sill may be laid next, if a post is to be carried, or else planking may be used, laid at 90 deg. to the course below.

Figure 156 shows a typical footing detail used in a temporary footing.

For large timber posts, bearing plates of steel are sometimes used to distribute the load.

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CHAPTER XI

TEMPORARY CONSTRUCTION

Probably no single phase of construction is so often misunderstood and inadequately handled as temporary construction. The appearance of the finished structure and the speed and economy with which it can be completed are largely dependent on the efficient construction of forms, centering, and falsework. Haphazard methods are too common and very expensive.

Foregoing chapters contain facts governing the use of wood in the general building and construction field and contain numerous illustrations of up-to-date methods of framing lumber in permanent construction. In the whole subject of wood utilization, however, there is no greater need for accurate authoritative information than exists in the field of temporary construction. Such data as are available are either out of date or apply only to some special structure.

The temporary use of lumber in the construction of reinforced-concrete or steel structures is important. Material and labor costs involved in this phase of construction represent a large percentage of the total cost. The cost of form work for certain types of industrial buildings, for example, is almost 15 per cent of the cost of the completed building. Intelligent planning and execution of form work and falsework should have the support of the construction engineer.

Cost variations of considerable magnitude occur between two jobs of similar size and character, though the efficiency of the labor element is approximately identical. This condition frequently results because the smaller contractor has recourse to concerns which furnish and erect forms at a lump price, thereby losing possible economies which might prevail if he had a better understanding of form building and could construct the forms with his own organization.

A saving in material and labor can likewise be effected in the design and erection of centers for concrete-arch bridges, if the designer makes use of modern, up-to-date methods instead of leaving the design of centering to the contractor, as it so often is left at the present time. The contractor often does not have competent engineering advice, and, as a consequence, timbers heavier than necessary are used.

Besides form work, centering, and falsework, there are other temporary uses of wood in construction included in this chapter, such as sheet piling, mine timbering, and timbering for deep excavations. Recom-

mended methods of constructing these types of temporary work are described and illustrated.

ESSENTIAL FEATURES OF FORM WORK

Four essential features of form work are (1) to obtain the strength and stiffness necessary to support the dead load of the concrete, plus construction live loads, without sagging or bulging; (2) to build durably, particularly if the forms are to be re-used a number of times; (3) to obtain light construction by the economical use of material, using the minimum amount of lumber consistent with safe and strong design; and (4) to reduce carpentry labor to a minimum, in both erection and stripping, through intelligent designing and planning by experienced men.

LUMBER USED FOR FORMS

Lumber used for form work should be strong and light. Air-seasoned lumber is preferred, for green lumber will shrink and warp, and kiln-dried lumber tends to absorb water from the concrete and swell out of shape. Form lumber should be free from knots and coarse grain, because both will show on the finished concrete. Usually, a No. 2 common grade of lumber is the lowest which will give satisfaction, although many firms specify No. 1 common for all sheathing purposes. Either rough or dressed lumber may be used. Dressed lumber is easier to handle and if dressed on all sides is better adapted to all purposes, since it will be of a uniform thickness. Tongue-and-groove sheathing is desirable on all first-class work because of the smooth, finished effect it gives where the concrete surface is to be exposed to view. In some types of structures, however, a smooth finish is not of great importance, and in office buildings, the concrete is generally covered by plaster or a suspended ceiling. Consequently, tongue-and-groove boards are seldom used for forms in such types of construction.

On account of the difficulty of re-using lumber that is swelled from wetting, some builders use beveled-edged boards, which have been well dried; other builders use ordinary dressed lumber laid with fairly loose joints and count on the swelling of the lumber to tighten the joints. This practice, however, is not recommended, as it permits leakage and causes fins on the surface of the concrete.

The lumber used for forms will vary with the locality. The ideal combination is strength and lightness. White pine, spruce, and the softer southern pines are the best. Spruce, if obtainable, is one of the best woods for all-around form use; white pine is expensive but is often used for cornices and other work requiring exceptionally smooth finish; Douglas fir and southern pine are used where strength is required.

It is sometimes not economical to rework second-hand lumber for forms. Old lumber must be pulled apart, and nails drawn, after which

it must be carefully cleaned. Even then it may sometimes have so much concrete adhering that it will dull tools. Under these conditions it may cost more to construct forms of old lumber.

End-matched Lumber.—The end-matching principle[1] discussed and illustrated in Chap. VIII, page 300, applies also to form work. End matching furnishes the contractor random-length lumber that is ready for installation with very much less waste and less labor cost than material of the so-called standard lengths. Experience has shown that from 10 to 30 per cent of what square-end material would cost laid, can be saved.

Boards for concrete forms are subject to concentrated loads and shocks during erection of the structure. Since such loads and shocks may be applied anywhere, the strength of end-matched joints that come between joists or other supports is of considerable importance. This and other questions led the Forest Products Laboratory recently to conduct a series of tests on end-matched lumber. A report from the laboratory shows that the tests indicate that random-length, end-matched pieces may be used for concrete forms, in place of so-called standard-length lumber jointed on supports, without appreciable loss of efficiency in distributing concentrated loads, stiffening the construction, and improving the alignment of supports. This, however, is with the provision that no more short pieces are included than are necessary for the elimination of loose knots, knot holes, and other defects which extend through the board.

Tests have not been made to compare concrete cast against forms made of end-matched lumber with concrete cast against forms made of standard-length lumber jointed on supports. Comparisons between end-matched and standard-length lumber can, however, be more readily obtained from actual service tests and observations than from laboratory experiments.

Sizes of Lumber.—The sizes of lumber used for form work depend, first, on what is readily obtainable at a reasonable price and, second, on the loads that are to be carried. If desired sizes are not available for the forms, then the forms should be designed to utilize what is available, changing the spans to suit. Nominal sizes in general use are as follows:

Sheathing and paneling	1 in. T. & G. stock or plain lumber
Sheathing and paneling	1½ in. T. & G. stock or plain lumber (if to be re-used several times)
Beam bottoms	2 in.
Joists	2 by 4 in. up to 3 by 10 in. (2 by 6 in. are commonly used)
Yokes	3 or 4 by 4 in.
Posts	3 by 4 in. to 6 by 6 in.
Studs	2 by 4 in. to 6 by 6 in.

[1] "End-matched Softwood Lumber and Its Uses," National Committee on Wood Utilization, Government Printing Office, Washington, D. C.

Short-length lumber[1] can often be advantageously used for cleats, yokes, braces, etc., with resultant savings in both material and labor.

In general, the actual thickness of lumber received on the job, for members less than 6 by 6 in., is $\frac{3}{8}$ in. less than the nominal size; and for timbers 6 by 6 in. and larger, $\frac{1}{2}$ in. less than nominal size, thus:

Nominal	Actual
3 by 4 in.	$2\frac{5}{8}$ by $3\frac{5}{8}$ in.
4 by 6 in.	$3\frac{5}{8}$ by $5\frac{5}{8}$ in.
6 by 10 in.	$5\frac{1}{2}$ by $9\frac{1}{2}$ in.

One-inch sheathing is dressed to $^{25}\frac{}{32}$ in., and $1\frac{1}{2}$ in. to $1\frac{5}{16}$ in.

FUNDAMENTAL PRINCIPLES OF FORM DESIGN

The design of the forms should be considered when the building or structure is being designed, particularly if the design and construction of both are to be carried on by the same organization.

Economy of material and, chiefly, economy of labor, as it is involved in the stripping of forms, should be carefully considered, and simple, economical arrangements for design should be selected. Tight forms which prevent leakage and seepage through cracks and thus avoid the formation of ridges which have to be chipped off the finished concrete surface are an important element in form economy; they must also be strong enough to sustain the weight of the concrete. By using actual rather than nominal lumber sizes in designing beams, girders, and columns, both material and the labor of cutting and fitting are saved. Column widths and beam-and-girder widths and depths should be in units of standard board widths. Thus, a 12-in. girder requires an $11\frac{1}{2}$-in. board in actual dressed size for the bottom, plus a $\frac{1}{2}$-in. strip to fill out. Obviously, it is simpler to design an $11\frac{1}{2}$-in. girder and to increase its depth accordingly, to take care of the slight decrease in width.

Simplicity of design is the real measure of economy in form construction, as it affects the amount of carpenter labor and reduces the possibility of mistakes. Sometimes, larger sizes of lumber than those theoretically required can be used economically if the forms are to be re-used a number of times.

Uniformity in the design of the form work and of the structure itself lessens the chance of error in both and, by allowing the re-use of forms, greatly decreases the required amount of labor and material. Forms should be designed so that they may be easily removed and re-erected without damage to themselves or to the concrete. The different shapes into which concrete is formed means that each job will present some new problems to be solved; but there are typical forms that will cover a large part of concrete construction. Aside from the saving of material and

[1] "The Marketing of Short-Length Lumber," National Committee on Wood Utilization, Government Printing Office, Washington, D. C.

labor on the form work itself, the re-use of forms permits a certain scheduled speed on the job without increasing the labor force and without interruptions. A day lost may mean actually a week lost, due to the effect on the rest of the job.

FRAMING METHODS

Column forms consist of four panels, one for each side of the column. The panels are made up of vertical tongue-and-groove sheathing 1 to 1½ in. in thickness or of 1¼-in. plain, square-edged boards. The sheathing or boards which go into these panels are held together by horizontal yokes, nailed to yokes on two opposite sides of the columns and projecting beyond the column so that they may be held tightly against the column sides by bolts. Wedges, as shown in Fig. 157, will hold the yokes on the other two sides of the columns in place. Instead of this method of yokes, bolts, and wedges, metal column clamps are often used. These clamps consist of thin strips of iron, encircling the columns and tightly and securely clamped by means of patented devices. The height of the columns, for the purposes of form design, can be measured up to the underside of the lowest connecting beam; the pouring should stop there, to permit settling of the concrete and to avoid cracks at the beam-and-column joints. Column yokes are usually either 3- by 4-in. or 4- by 4-in.; when 3- by 4-in. lumber is used, the variable spacing, as indicated in Fig. 158, should be used, the first yoke being placed about 4 in. from the bottom. The closest spacing of yokes is at the bottom of the columns. The use of this spacing schedule will save at least one yoke per column side, over the method of equal spacing, and more than make up any labor costs due to alleged difficulty to the carpenter. If column forms are to be re-used, they should be designed for the worst possible conditions. Figure 159 indicates an approved method of spacing 4- by 4-in. yokes, the spacing being constant for all column sizes and varying only with the height of the column. To use a column form 15 ft. high on a column having the same cross-section but only 13 ft. high, it is necessary only to cut off the lower 2 ft., as is indicated in the figure.

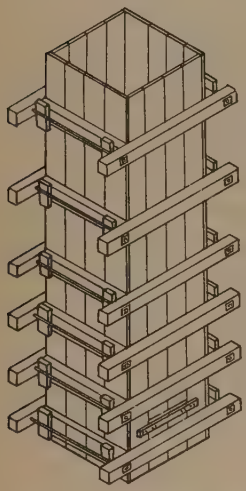


Fig. 157.—Column form.

Beam-and-girder Forms.—The bottoms of the beam-and-girder forms should be constructed of 2-in. lumber of requisite width, and the sides of 1- to 1½-in. lumber battened together. The sides of beams should always be placed at the side of the beam bottom and may be either nailed to it or tied together by wires or braces underneath the beam. The sides should also be braced at the top, to prevent spreading.

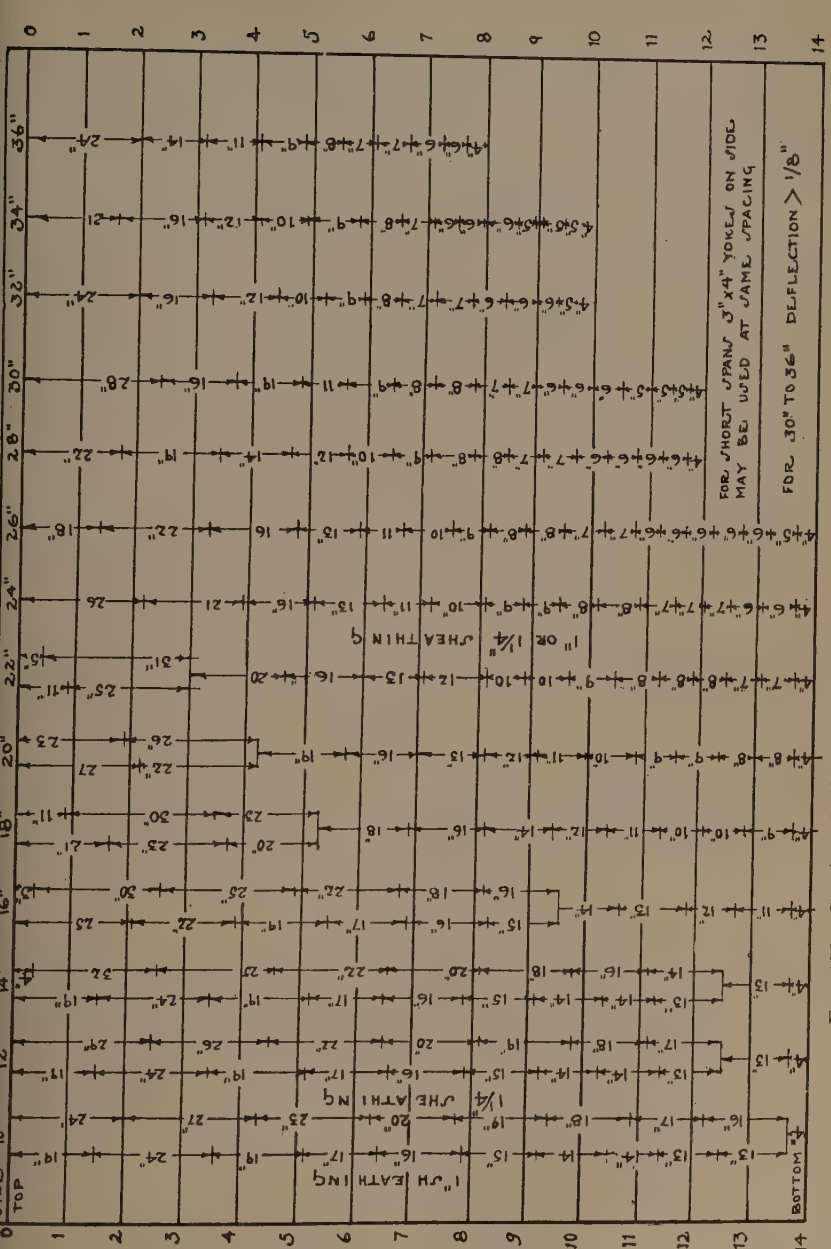
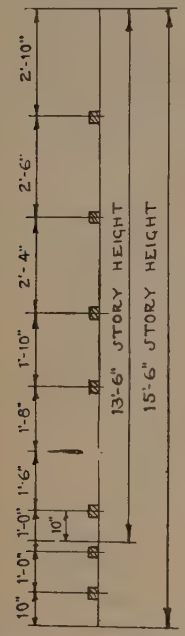

HEIGHT OF COLUMN
FT. 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
SIZE TOP
10" 12" 14" 16" 18" 20" 22" 24" 26" 28" 30" 32" 34" 36"
BOTTOM
1" SHEATHING
1 1/4" SHEATHING
1" OR 1 1/4" SHEATHING
FOR SHORT SPANS 3"X4" YOKES ON SIDE MAY BE USED AT SAME SPACING
FOR 30" TO 36" DEFLECTION > 1/8"

FIG. 158.—Spacing of column yokes for various sizes and heights of column.

Figure 160 shows a typical assembly of beam, girder, and column forms. Note the two methods of framing the beam bottom and sides into the girders. Either of these methods will permit easy stripping, yet it is a common sight to see beam sides and girder sides carried into the connecting girder or column, where the ends will be embedded in concrete. As a result, stripping is made more difficult, boards are broken or crushed, and grooves are left at the corners where the boards have been pulled out of the concrete.



APPROVED METHOD OF YOKE SPACING ON COLUMNS

Fig. 159.

Posts.—Posts must be provided at proper intervals under the bottoms of beams and girders. The spacing of posts, when 2-in. dressed lumber is used for the beam or girder bottom, and when the maximum deflection is limited to $\frac{1}{8}$ in. for a construction live load of 40 lb. per square foot, exclusive of the weight of the concrete and forms, is as follows:

Depth of Beam	Space Posts
Up to 16 in.....	4 ft. 3 in. apart
16 to 24 in.....	4 ft. 0 in. apart
24 to 38 in.....	3 ft. 9 in. apart
36 to 48 in.....	3 ft. 6 in. apart

A cap or tee head should be used on the top of each post and braced back to the post in order to get the full bearing on the beam bottom, as indicated in Fig. 160. The spacing of the posts fixes the span of the stringers which support the panels. On large jobs, it is always well in designing to try two or three different layouts, to determine the most economical, considering the labor of erecting and stripping and the cost of the material. To eliminate the labor of cutting and fitting shores or posts to support the floor beams and girders, patented, adjustable shores, such as the Rooshor, illustrated in Fig. 161, are extensively used. This particular shore consists of two vertical timbers and a headpiece sliding on a pipe, with a locking device at the bottom of the timbers to hold the load. These shores can be used as posts after the concrete has set, and when it is desired to strip part of the forms, as many of these shores as are needed can be left in place. It takes but a moment for one or two men to place one of them. The safe working load is 3,000 lb. Various similar devices are in wide use.

Slab Panels.—Slab panels are constructed of tongue-and-groove or square-edge boards fastened with battens of 1 by 4 in. or some other suitable size. These panels rest on the edges of the forms for the sides of

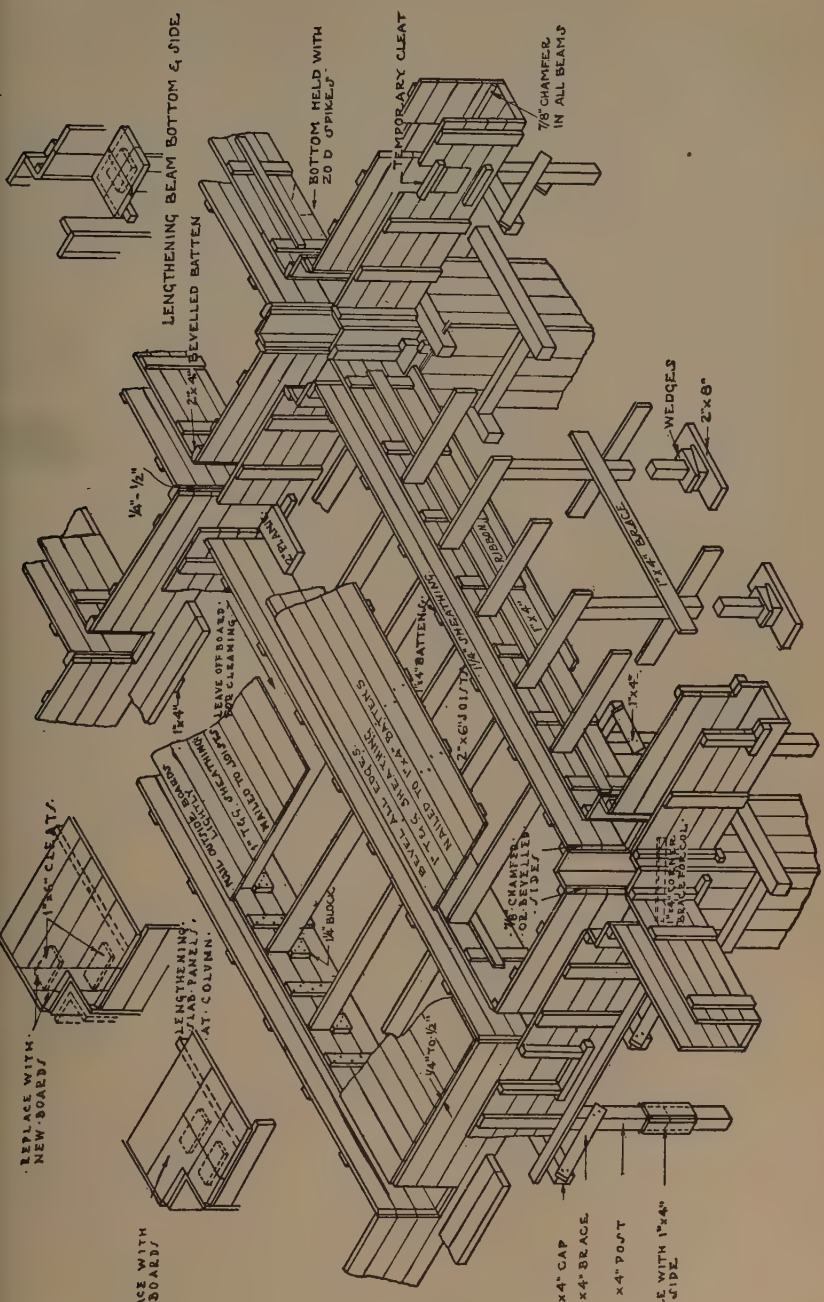


FIG. 160.—Typical assembly of beam, girder, and column forms.

the beam or girder and are also supported by joists running between the beams. The joists, in turn, should rest on runners or ledgers, nailed horizontally to the battens along the beam sides, as indicated in Fig. 160. Some builders simply lay 1- or 1½-in. boards on joists spaced approximately 30 in. on centers and nail them to every other joist.

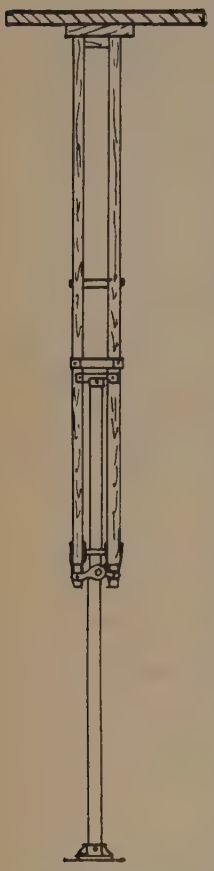


Fig. 161.—Adjustable shore.

Mushroom-slab Construction.—In flat- or mushroom-slab floor construction, the slabs are supported by columns having inverted cone-shaped tops. For relatively heavy loads, a drop panel, square in shape, is usually built over the columns a few inches deeper than the slab, as shown in Fig. 162. For lighter loads, it is considered more economical to omit the drop panel and to use a slightly thicker slab throughout.

As this type of construction has no beams or girders, the forms are much simpler than those in which the ordinary beam-and-girder type of construction is used. Two general types of forms for this flat-slab system are in use. The first consists of slab panels cleated together, resting on joists which are supported directly by the posts; the second, of panels resting on joists which are carried on ledgers running crossways and supported by posts. This second method, which is shown in the figure, generally requires less lumber than the first. To facilitate stripping, the drop-panel forms are often built on separate units, supported by a double bent or by the main floor joists. They are usually built in two sections for ease in handling. The column forms are generally of wood and have no part in supporting the slab forms. The column caps are almost always round, and, hence, a steel form is practically always used.

Rib Floors.—Rib floors, which are used in buildings with light live loads, consist of fillers of hollow tile or other similar material between ribs of concrete.

In determining the type of deck to use for the form work, the chief factor is the spacing of the ribs. When clay fillers are used, however, the forms are customarily built with a "closed deck" similar to that used with the ordinary beam-and-girder construction, the floor being completely sheathed.

When other kinds of fillers are used, "open-deck" forms may be employed, although this type of form work is hazardous to workmen and tends to increase the cost of labor. The open-deck forms differ from

others in that boards are used under the ribs only, the rest of the flooring being omitted. The fillers rest on these boards and also act as forms for the concrete. If ribs are spaced 16 in. on centers, a closed deck seems

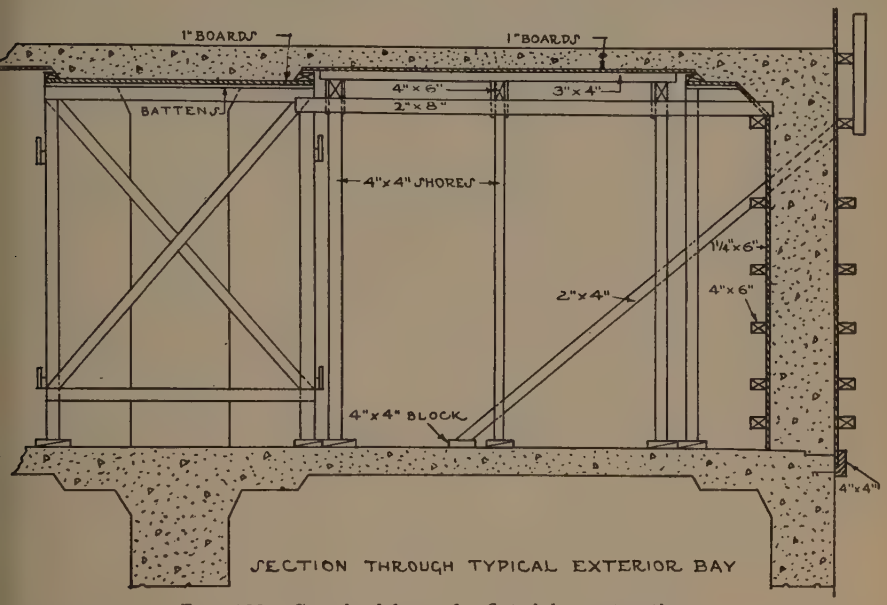


FIG. 162.—Standard forms for flat-slab construction.

preferable; but if they are spaced 25 in. on centers, an open deck is probably more economical. These types are illustrated by Figs. 163 and 164.

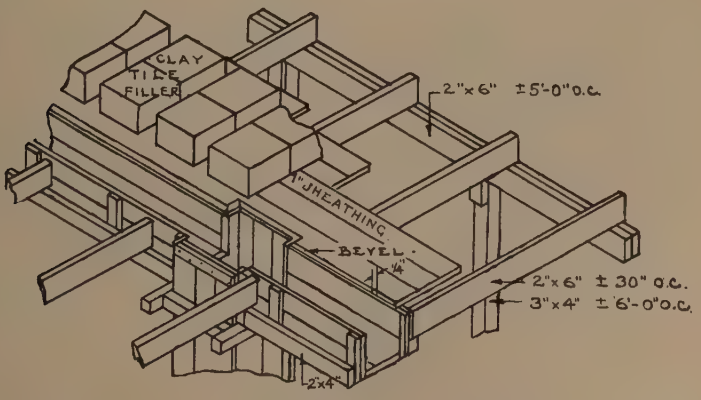


FIG. 163.—Closed deck for clay tile filler.

Forms for Fireproofing Structural Steel.—Forms used for the fireproofing of structural steel are comparatively light and simple. Cinder concrete weighing only 100 lb. per cubic foot is chiefly used in the East,

particularly around New York City, but in the Middle West and West, stone concrete is used. For columns, the forms are similar to but lighter than those used for reinforced-concrete construction.

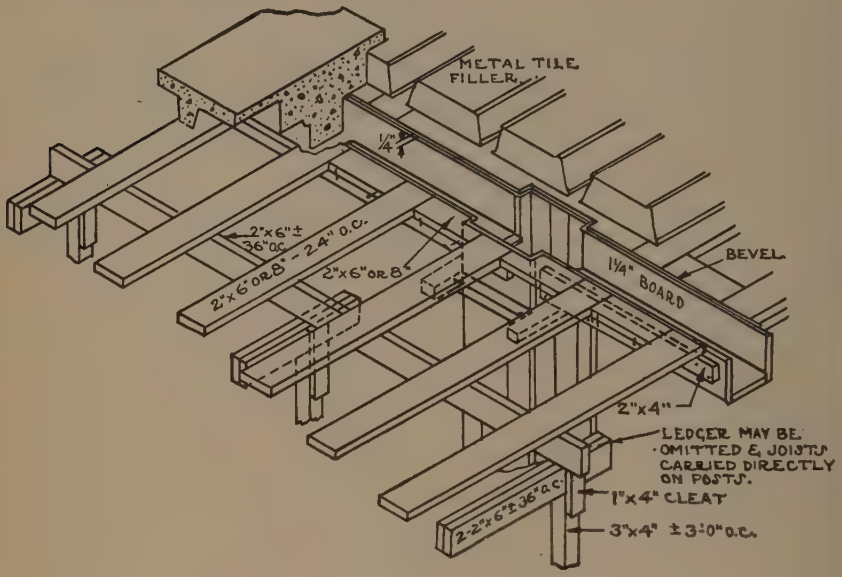


FIG. 164.—Open deck for metal tile filler.

Floor forms, instead of being supported by shores, are always hung from steel beams either by wires, commonly of 6 or 7 gage, or by special patented clamps and ties. In the design of the form work, the size of stringers and joists will depend upon strength in bending rather than upon

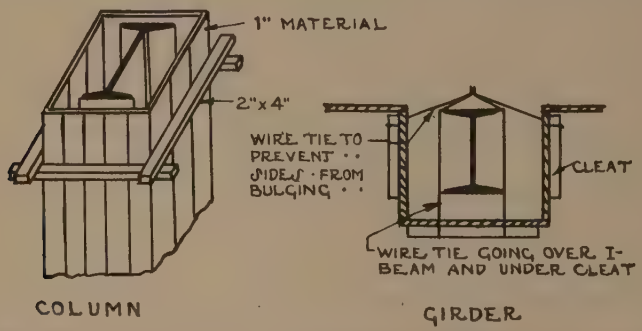


FIG. 165.—Forms for use where concrete is employed to fireproof structural-steel members

resistance to deflection, since the concrete will nearly always be covered by plastering, or a suspended ceiling, and small deflections will not be noticeable. Stringers 1- by 6-in. spaced 2- to 2½-ft. are hung through wire loops over the I beams. These stringers, in turn, support the

runners or joists upon which the sheathing rests. Figure 165 shows a simple type of form for both columns and girders.

FACTORS AFFECTING DESIGN OF FORMS

Triangular fillets or chamfer strips, shown in Figs. 199 and 200, are usually inserted at corners of columns, beams, and girders, to avoid the square corners which are likely to break off or chip. Either method facilitates stripping and improves the appearance of the finished work. Many designers use a camber of ¼-in. to every 10 ft. for beam-and-girder forms to counteract deflection. Heads of doors and windows should be braced to avoid the slightest sag; otherwise, the door and window frames will not set tightly. Sheathing for wall forms is usually supported by vertical studs. The spacing of studs is limited by the strength of the sheathing. The studs on opposite sides of the wall may be held in place either by wire ties through the wall at each stud or by using horizontal wales over the studding; this latter is a common practice. When wales are used they must have a bearing against each stud. If necessary, wedges may be inserted between the wale and stud. The wales are tied together by bolts through the walls at proper intervals.

The use of wales avoids tie wires or bolts at each stud and reduces the size of the studs required. For walls over 12 ft. high, unless the strength and watertightness requirements make it imperative to pour without having a break in the concrete, the forms are usually built for only half of the height and then raised for re-use in the top half.

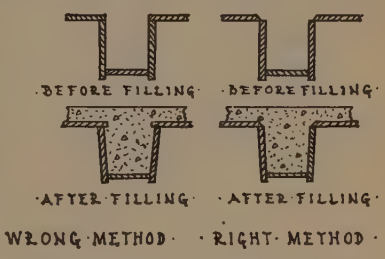


FIG. 166.—Right and wrong ways of framing beam and floor-panel forms.

Forms must be designed so that they can be easily removed. There always will be slight movements of the forms due to the weight of concrete. It is necessary, therefore, to give particular care to the joints made by the different units and to allow sufficient clearance for any movement of the forms. This is well illustrated in the joint where a floor panel rests on a beam side. The panel should have a beveled edge and project only about halfway onto the beam side. If the edge of the panel is made flush with the inside face of the beam before the form is filled, it will be found to be projecting into the concrete of the beam when the time comes to strip it, due to the fact that the sides of the beam spread slightly from the weight of the concrete. Figure 166 shows right and wrong ways of making such connections. The upper figures show the forms before filling, and the lower figures the position the beam sides take due to the pressure of the concrete. Similarly, beam bottoms and sides, when they overlap and rest on girder or column sides or when constructed

to rest on cleats, should have clearance as indicated in Fig. 198. The ends should be beveled as shown.

Loads and Stresses.—The loads to be considered in the design of form work are the dead load of the concrete and forms and the construction live load. Usually, the weight of forms is small and need not be considered. For ease in computing, the weight of the concrete can be figured at 144 lb. per cubic foot. Then, the weight of the slab per square foot will be twelve times it thickness, and the weight of the beam per linear foot will be the product of its depth times its width. In the design, the construction live load due to impact and walking over forms should be taken at 75 lb. per square foot. In checking joists for deflection, 40 lb. per square foot may be safely used, since any load in excess of this will be present only momentarily during actual concreting.

The hydrostatic pressure of the wet liquid concrete must be considered in the design of forms for columns and walls. One authority recommends 125 lb. per cubic foot for columns; a pressure equivalent to that of a liquid weighing about 145 lb. per cubic foot, for walls up to 5 ft. high; 125 lb. per cubic foot for walls from 10 to 20 ft. high; and 75 lb. per cubic foot for walls over 20 ft. high. These figures, however, are subject to certain limitations. The correct value to use is largely dependent upon the rate of pouring—that is, on whether the wall is to be poured 2 or 4 ft. or some other height at one time. It also depends upon the time it takes to pour the entire height of the wall, since after the concrete has set the hydrostatic pressure is zero. It may be concluded from tests conducted by the Bureau of Standards that the greatest pressure head that need be considered will not be greater than the depth which will be poured in 40 min.

Unit Stresses.—Unit stresses, as given in the tables in Chap. II, may be used in form-work design, although, in view of the temporary nature of the work, larger working stresses are permissible. A column formula commonly used to determine the safe unit stress in columns or posts is $S = 1{,}100\left(1 - \frac{l}{60d}\right)$. S equals safe unit stress, which here, of course, will be also the safe load in pounds per square inch; 1,100 equals safe working stress for lumber used; l equals unsupported length in inches; d equals least dimension in inches. Some builders increase this to $S = 1{,}600\left(1 - \frac{l}{60d}\right)$ when better grades of southern pine or Douglas fir are used. Ordinarily, the stress computed as above will be about twice that allowable for compression across the grain, in the horizontal timber resting on the post. Accordingly, the size of post will usually be governed by the lower unit stress allowable for compression across the grain.

Deflection.—There is a wide difference of opinion as to the amount of deflection which should be allowed in form-work design. Best practice

indicates that forms should be designed so that the deflection will not exceed $\frac{1}{8}$ in.; greater allowances, such as $\frac{1}{360}$ of span, a value in common use, may result in wavy floors and surfaces. In computing, take E, modulus of elasticity, from the tables in Chap. II. Thickness of sheathing will usually be limited by deflection.

Layout and Other Influencing Factors.—For large jobs, it is advisable to use a key plan showing the locations of columns, panel units, beams, and girders, with an appropriate number and letter for each, in order to secure quick and easy identification of forms. A key plan should be provided for each floor unless the floors are the same in plan. In large buildings it is customary to treat half a floor as one floor or a unit in making up the forms. Careful consideration should be given to the size and spacing of shores. Story height is an important feature, for, while 4- by 4-in. posts 12 ft. long will carry $3\frac{1}{2}$ tons, if these same posts were 16 ft. long, they would carry only about $1\frac{1}{2}$ tons safely. A number of light shores may prove to be more economical than a smaller number of heavier shores. The size of the job, the story height, the speed of concreting, and the re-use of forms and of shoring should be kept in mind in planning the form layout. The re-use of forms is particularly important, because it affects the selection of the sizes of slab units and of columns, which will be used a number of times, and so determines the actual quantity of form lumber to be ordered.

Another factor to be considered is the character of soil and foundation. On soft or frozen ground, for instance, where a dangerous sag or even failure in the forms might develop, sound lumber, of sufficient width, strength, and thickness to distribute and carry the load, should be firmly bedded on the ground. At one building site, where a firm subgrade was overlain with marsh land, 2-in. second-hand lumber on 2-ft. centers was spread over the entire basement area. On top of these planks and at right angles to them, 3-in. second-hand lumber was then placed under each row of shores. This successfully provided against settlement and was undoubtedly a good investment.

Design Data.—Form members subject to bending must be designed for (*a*) bending moment, (*b*) shear, (*c*) deflection, and (*d*) bearing or crushing.

The design of posts will depend on height, as affecting allowable unit stress and resulting cross-section needed, and on crushing across the grain of the horizontal member bearing on the post. Crushing will usually be the governing factor.

The following formulæ may be found in any standard book on mechanics and should be used only with a clear conception of the principles involved.

Flexure formula $\frac{SI}{c} = M$ or $S = \frac{Mc}{I}$.

M = bending moment.

S = horizontal unit stress (tensile or compressive) = 1200 lb. per square inch (assumed).

$\frac{I}{c}$ = section factor.

$$M = \frac{SI}{c} = S\,\frac{bd^2}{6}.$$

$$M = \frac{wl^2}{8} \text{ for simply supported member uniformly loaded,}$$

where w = uniform load per linear foot and

l = length of span.

Equating the values of M for bending, uniform loading (one span),

$$l = \sqrt{\frac{133.33\ bd^2}{w}}$$

for bending, uniform loading (continuous over supports),

$$l = \sqrt{\frac{166.67\ bd^2}{w}}$$

It is common practice to design members as partially continuous when they extend over more than two supports, taking the bending moment as $M = \frac{wl^2}{10}$ for uniform load. Floor, wall, and column sheathing will always be partially continuous.

On short spans and with heavy loads, where only a small depth is required for bending it will often happen that the member will not be strong enough to resist shear. The size will then have to be increased, to allow a safe unit shearing stress.

The unit shearing stress $v = 1.5\frac{V}{bd}$

v = 80 lb. per square inch (assumed)

V = vertical shear

$$\therefore bd = \frac{1.5V}{80}$$

The deflection of form members must be limited, or there will be wavy lines on the concrete and cracks in the finished floor surfaces. When the depth required for bending is small, the allowable deflection will usually govern the size to be used. This is particularly the case with sheathing.

For uniform load and single span,

$$D \text{ (deflection)} = \frac{5}{384} \cdot \frac{w}{12}\,\frac{(l.12)^4}{EI}$$

For deflection (not to exceed $\frac{1}{8}$ in.)

$$l \text{ (max. span in feet)} = 2.04\sqrt{d}$$

where d = *depth of member in inches and* $E = 1{,}200{,}000$

For uniform load and continuous span

$$D = \frac{3}{384} \cdot \frac{w}{12} \frac{(l.12)^4}{EI}$$

For deflection (not to exceed $\frac{1}{8}$ in.)

$$l \text{ (max. span in feet)} = 2.357\sqrt{d}$$

For bearing, the area needed to prevent crushing of grain equals $V/400$, where 400 is allowable crushing stress in pounds per square inch across grain.

METHODS OF FASTENING FORMS

Most forms are built up by nailing. The cost of stripping is lowered by using a minimum number of nails. It is sometimes advantageous, also, to use nails with double heads as shown in Fig. 167, so that they may be drawn easily. Column sides, however, should be held in place by bolted yokes on jobs where the forms are to be re-used. Wall forms may be tied through the wall by wire or by bolts through the studs and wales. The choice of wire or bolts and the proper size to use is mostly a matter of practical experience. Soft-iron wire is preferred to steel, as it is less likely to break when twisted. When a fluid, particularly an oil, is to be contained in a concrete structure, the use of wires or bolts to tie the wall forms together will result in leaks wherever these ties are withdrawn from the concrete.

Fig. 167.—Double-headed nail.

Bolts.—The rate of pouring the concrete in wall forms is a factor to be considered in specifying wire and bolts. The faster the pouring the stronger the fastening should be. Bolts should not be used in wall forms without wales, except with double studding, in which case, the bolts, placed between the studs, bear on blocks or short pieces of timber, as illustrated in Fig. 168.

The bolt size needed is seldom calculated on the medium-sized job, for the theoretical size required will nearly always be found smaller than good practice indicates. The minimum size to be used is $\frac{1}{2}$ in., but $\frac{5}{8}$ in. is the usual size for column yoke bolts, as they must be strong enough to withstand the insertion of wedges between the bolt and the side of the column, without bending. In large columns or other units of heavy construction, the size of the bolts should be calculated.

Washers.—Washers should be used to transmit the stress in the bolt to the yoke or stud, so that crushing of the wood fiber will not occur. The washer must also be thick and strong, so that it will not bend or break. A standard size sufficient to meet all ordinary condi-

tions should be adopted for a given job, or group of jobs. Washers are usually from 3 to 3½ in. in diameter and ⅛ to ¼ in. thick.

Spacers.—Spacers should be used in all wall forms, to hold the sides apart when the wire ties or bolts are made snug. Pieces of wood 1 by 2 in. are commonly used and removed as soon as the concrete reaches them.

Patented Form-work Accessories.—Many patented devices have been put on the market to eliminate the labor ordinarily required to fasten forms. The economy of these devices usually depends upon the number

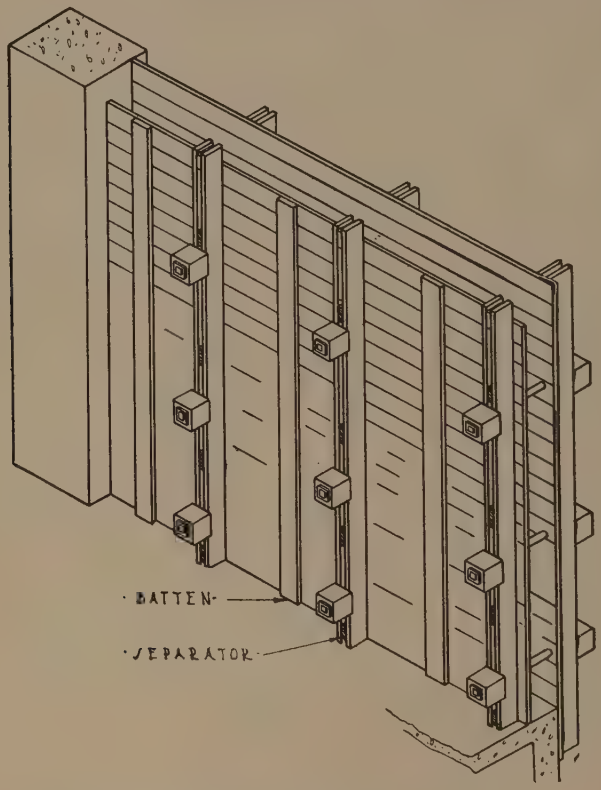


FIG. 168.—Method of holding wall forms in place.

of times they can be used. Contractors doing a considerable amount of form work can economically use plain, round rods with patented clamps or various types of patented rods and clamps, particularly in walls which are under hydrostatic pressure. Several patented fastening devices are illustrated.

Figure 169 shows the *Tyecrus*, a combination wall spreader and tie, which is made of two No. 4 wires, welded to helix of wire at each end, forming a threaded opening for ½-in. lag screws. In Fig. 170 the *Hawley* tie bolt is illustrated. It consists of three parts, a center rod threaded at

each end which remains in the wall, and two removable end-rods each fitted with washer and nut. Figure 171 shows *Universal* rod couplings,

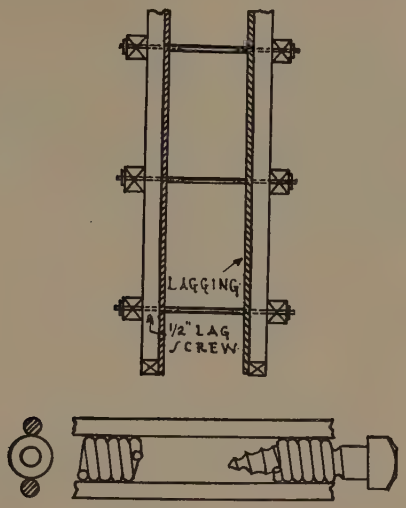


FIG. 169.—Combination wall spreader and tie.

which have a center and two end rods, threaded at each end and connected by two cone nuts, adjusted to space the forms. The *Universal*

FIG. 170.—Tie bolt.

wire clamps shown in Fig. 172 are locking clamps for tie wire. Figure 173 illustrates the *Bullis* clamp for forms. It is devised to tighten wires

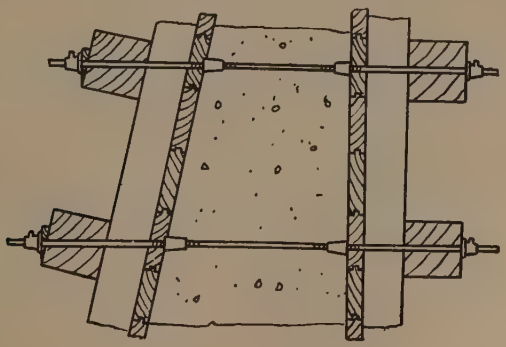


FIG. 171.—Rod couplings.

on the outside of the forms, by passing them through the clamp and turning it until they are tight, then nailing it to the stud. The *M and M*

clamps shown in Fig. 174 have the ends of the wire inserted in slots and tightened, then clamped. Figure 175 illustrates the *Marion* wall tie. This is a malleable-iron tightener having the tension of wire governed by

Fig. 172.—Locking wire clamp for tie wire.

Fig. 173.—Form clamp.

removable bolts, and Fig. 176 shows a *Universal* column clamp which is to be slipped over a plain rod or bolt; the rod is then depressed and clamped by a set screw. In Fig. 177 the *Symons* column clamp is shown.

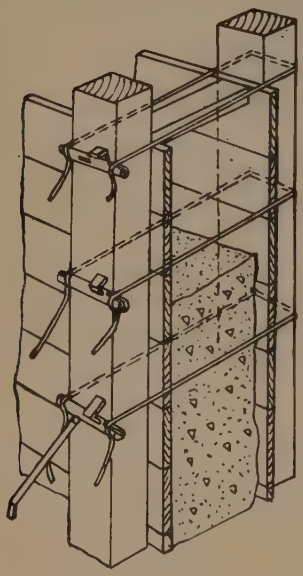


Fig. 174.—Wire clamps.

Fig. 175.—Wall tie.

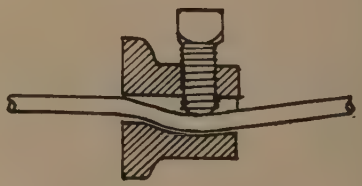


Fig. 176.—Column clamp.

It consists of two pairs of pivoted steel arms, so perforated as to allow the dropping of 50-d nails through the overlapping holes and malleable-iron bracket. The form is automatically squared. The *M and M*

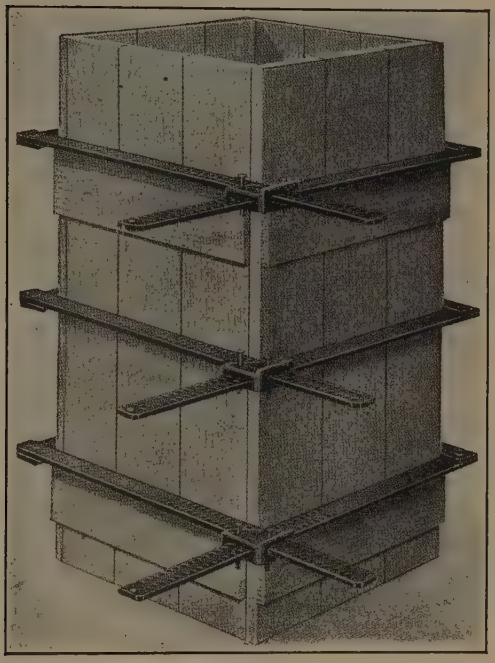


FIG. 177.—Column clamp.

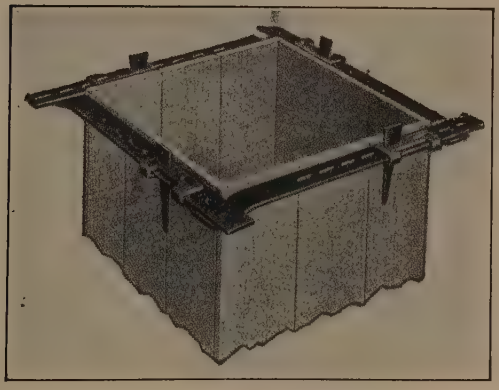


FIG. 178.—Column clamp.

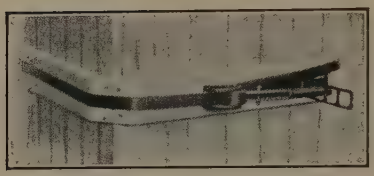


FIG. 179.—Column clamp.

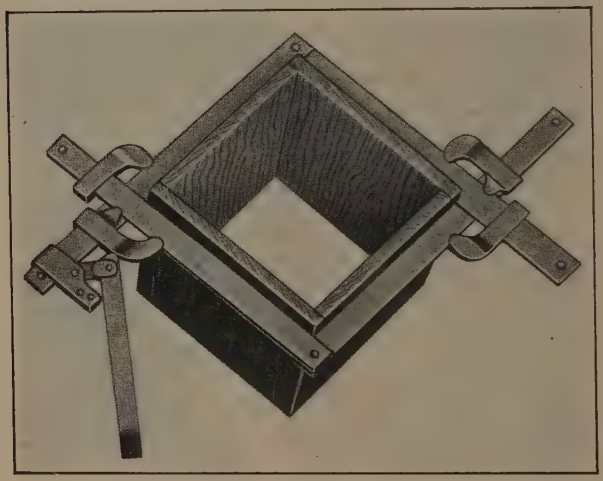


FIG. 180.—Adjustable column clamp.

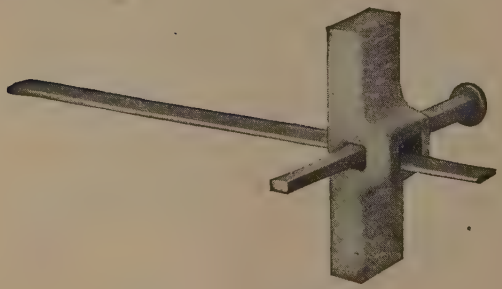


FIG. 181.—Band clamp.

column clamp shown in Fig. 178 has four slotted arms held in place by wedges driven through them. Figure 179, the *Sterling* clamp, is a band clamp of 16-gage band steel $1\frac{1}{8}$ in. wide, which encircles the column. A ratchet attached to one end of the band draws and fastens the clamp by means of a hand lever. Figure 180 shows an *O.D.G.* clamp, which consists of two units having two steel bars hinged together with two steel castings on each unit. The castings grip the bars at any point, being tightened by a lever arm. The *Universal* band clamp, shown in Fig. 181, has a steel band which encircles the column and is tightened and held by a ratchet and lever.

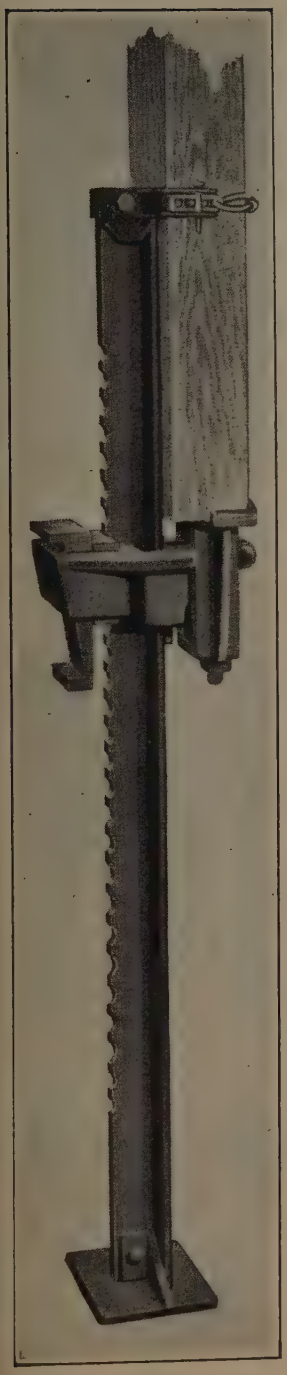


FIG. 182.—Shore jack.

FIG. 183.—Adjustable shore.

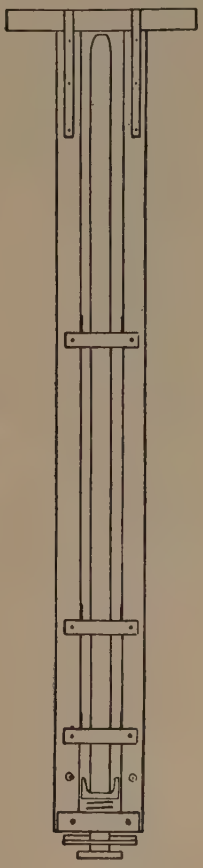


FIG. 184.—Adjustable channel shore.

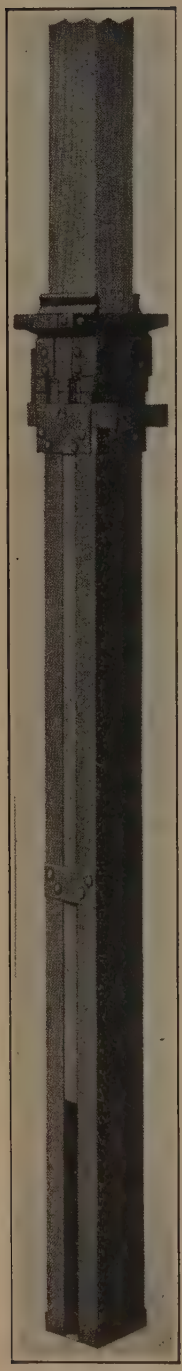


Fig. 185.—Adjustable square shore.

There are, also, numerous types of adjustable shores, and a few of them are shown.

The *Symons* shore, shown in Fig. 182, has a T-shaped post fastened to a square steel base, with a collar at the top through which timber passes and slides on the post. It is adjusted by clamp and notches. Figure 183 shows the *Universal* adjustable shore, which has four steel angles fitting around the timber post. The steel T-shape passes through the slots and supports the posts; it is inserted at a desired height, and the final adjustment is made with a jack screw at the bottom. The *Atlas* is an adjustable shore shown in Fig. 184, and has a steel and wood head,

Fig. 186.—Adjustable shore.

fastened to the 2 by 4's, which slide over a pipe post, to which it can be locked at the height desired. Figure 185 shows the *O.D.G.* adjustable shores. They have two steel channels 5 ft. long which receive the timber post, raising and adjusting it by lever and clamp. Figure 186 illustrates the *Dayton* shore, which has two timber side pieces with timber head pieces, strapped together, which slide over a perforated pipe, having a jack screw at the bottom for adjustment.

CONSTRUCTION AND ERECTION OF FORMS

The chief considerations in the construction and erection of forms are (1) ease of stripping and (2) unit construction. On jobs of any size, ease of stripping and handling will be the chief factors in cutting labor costs. The development of form units (such as panels for slabs, beam sides and column sides with necessary joists, runners, and yokes) in advance of actual construction by carpenters working at some distance from the point of erection has an important bearing upon erection costs, because forms so made can be put in place by common labor, with a minimum of additional carpenter help. In large cities, however, union labor conditions usually make it necessary for carpenters to place all forms, although laborers may hoist and distribute them. Office drawings should be prepared, where possible, to indicate the details to the carpenter foreman and provide him with a schedule showing the number of the various units required. Each unit or piece of form should be marked with a symbol, to show where it is to be erected. Symbols should coincide with those shown on the key plan.

Foundation Forms.—That portion of the foundation walls which is below ground does not usually require forms unless the soil is porous or unstable. In a porous soil, whether it be stable or not, forms are desirable in order to prevent the water in the concrete from draining out into the soil. Forms for the section of wall aboveground are usually simple planks or panels held in line by stakes and braces, with wooden spreaders and wire ties.

The construction of foundation and wall forms is clearly shown in Figs. 187 and 188.

In most cases, it is necessary to provide both an inner and an outer form, because the earth side of the excavation will not stand up firmly. Both types of foundation wall forms are shown, however.

The sectional wall form shown in Fig. 189 is best used where only a small amount of wall is to be built at one time.

Rectangular Footings.—Footings for columns are nearly always rectangular. The four sides may be conveniently built up as panel units. The panels for one pair of opposite sides are made up to exact footing width, out of sheathing fastened with vertical cleats spaced 2 ft. on centers. If 2-in. dressed lumber is used for these cleats, a cleat should be placed

2 in. from either end of the panel, with a slight allowance for clearance, as shown in Fig. 190. The other pair of panels with cleats on the inside spaced the length of the footing plus twice the sheathing thickness, will

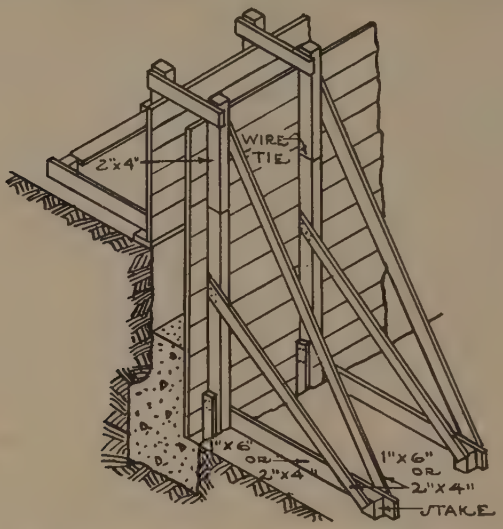


FIG. 187.—Wall form for foundation walls and cellar walls built in firm ground.

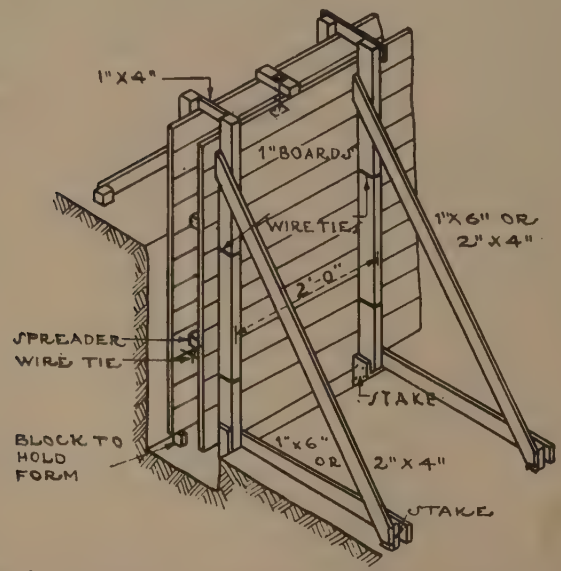
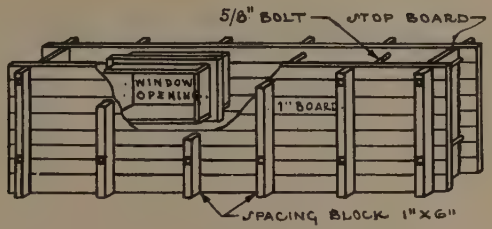


FIG. 188.—Form for foundation and cellar wall located in ground which is not firm.

then fit snugly against the first pair of panels, and the panels will support each other. The depth of the panels does not have to be cut down to the exact footing depth, since a nail can be placed to mark the top of

ne concrete; nor do the boards for the outside panels need to be cut to xact length, as indicated in the illustration. If wire ties are used, the oles through which the wire passes should be bored at the carpenter shop r wherever the panels are made up, so that there will be no delay in rection. Outside panels should be braced in the same way as wall



IG. 189.—Sectional wall form for carrying wall up vertically with minimum amount of lumber.

otings, and if reinforcing steel is used, it should be placed before the ire ties are put in. If the forms are not to be used a number of times, undation panels are often nailed together; but nailing is not satisfactory the forms are to be used again.

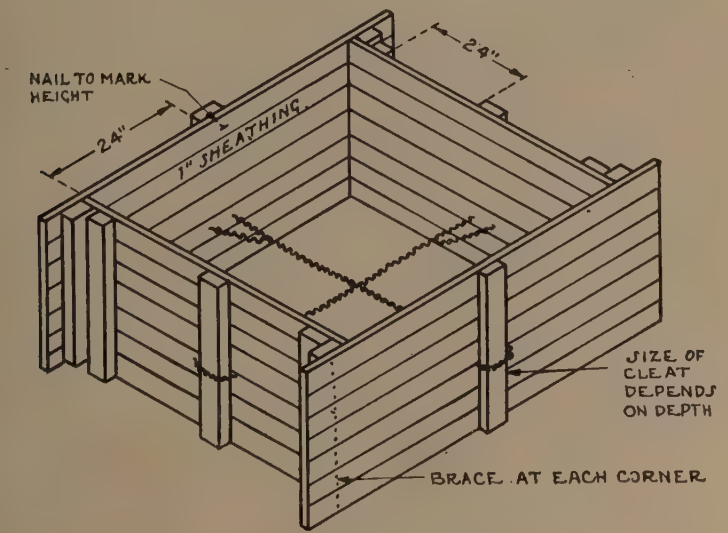


FIG. 190.—Square footing.

Stepped Footings.—The form units for stepped footings are similar those illustrated in Fig. 190. For the upper step forms, a support ust be provided which will not interfere with the concreting of the wer step. The method shown in Fig. 191 is a common one. Here, two eces of 2 by 4 in. or 4 by 4 in. are placed across the top of the lower

step, on either side of the upper step form. The upper step form is then nailed to these pieces. This method can be used only when the concrete is poured for a step at a time. If the entire footing is to be poured as a unit, stepped forms are seldom used; if they are used, however, the lower steps will have to be sheathed over and held down, as indicated by the dotted lines in the figure. Since the upward pressure on the covering boards will be considerable when all the concrete for a stepped footing is poured at one time, the top form must be held down securely by weights or by cleats, nailed to the 2- by 4-in. piece which supports the upper step form.

Pyramidal Footings.—The chief point to be considered in the development of forms for pyramidal or sloping-side footings is the weighing down

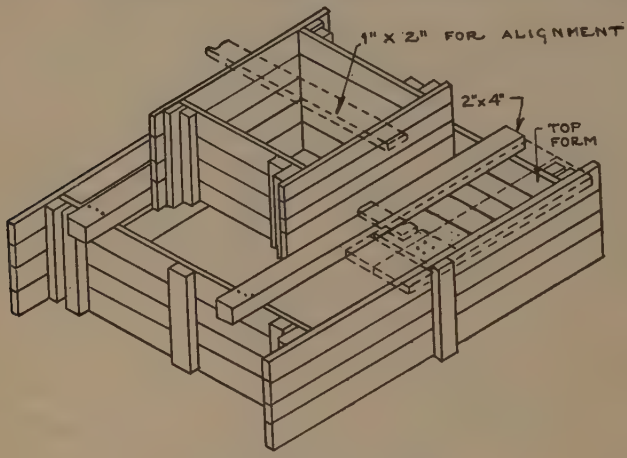


Fig. 191.—Stepped footing.

or wiring of the panels so that they will not lift up during concreting.

The number of footing forms for the same-sized footings to be built on a job will depend upon the speed of concreting. They can be stripped within 24 hours, as the footings will carry no load at that time.

If different-sized footing forms are needed, it is often possible and economical to make up and use the largest ones and then cut them down to smaller sizes, simply adding the necessary cleats.

Column Forms.—Column forms offer more opportunities to save money than the form work for any other part of a building. Except for round columns, the general method of framing form work is the same for all column shapes—namely, square, rectangular, L shaped, or octagonal.

For multiple-story buildings it is general practice to build only enough column forms to provide for one story. These forms are re-used for all story heights above the first floor. Though 1-in. lumber is satisfactory if the form is to be used only once or twice, 1½-in. boards are best where the forms are to be used several times.

It is customary to set the exterior columns first and to locate the others from these, working toward the center of the building. In flat-slab construction the columns are cut off square at the bottom of the inverted conical cap. In other types of construction the beams and girders frame into the column head. The best practice, in this case, is to build the head as a separate unit, building the column form only to the bottom of the beams which frame into it; this not only makes it easier to strip the column forms but also serves to avoid the danger of mistakes in cutting the beam openings wrong. It is easier to re-use the forms for the resulting shorter columns, when the head is made up separately. Many contractors use a measuring stick the length of the floor-to-floor height, which has marked on it the slab thickness, the floor sheathing, and the location of the bottom of both beams and girders, also the location of the yokes. This stick should have a mark 12 in. above the bottom. There is often a slight variation in the level of the concrete at the different columns, especially when the finished floor is put on as a separate operation later; and this mark 12 in. from the bottom of the stick is useful in determining the amount that should be cut off the bottom of the column form before it is erected. This stick marked out by the foreman, therefore, is used both in connection with assembling the panels and with their erection. It insures uniformity in measurements, saves the carpenter time and is a convenient device for preventing mistakes. The use of several stepladders also facilitates the erection of column forms.

In building the forms for the column sides in units, the two opposite panels, and, in the case of rectangular columns, the smaller sides, are built first. The width of these panels is the width of the column plus the thickness of the sheathing on each side. Yokes are next cut to this same exact length, laid out, and spaced by the measuring stick. The end board of the panel is then nailed to the yokes, allowing for the sheathing thickness. The other boards are pushed tightly against the first and nailed to the yokes, the last board being cut to the proper width, unless the column has been so designed as to utilize an exact number of boards. The other two side panels are built similarly, the width being the exact column dimension. The yokes attached to these panels, however, will project about 8 in. on each side, to clear the yokes on the adjacent panels and allow for bolt holes. Figure 157 illustrates a typical column form for interior rectangular columns. When the head of the column form is made part of the form, the openings for the beams must be cut in the panels at the time they are being made up. The openings for a particular-sized beam should never be the exact dimension of the beam but always greater; otherwise, when the beam sides give slightly under the pressure of the concrete, the edges of the openings in the panels will be embedded in the concrete, and it will be very difficult or impossible to

strip the panels. For the same reason, the beam sides should not be brought flush with the inside of the column sheathing; as in this case, the ends of the beam sides will be embedded in the concrete of the column. One method of avoiding these difficulties is to make the opening ¼ to ⅜ in. larger all around than the sides of the beam and to bevel the side and bottom edges inward at an angle of about 45 deg., as shown in Fig. 192*a*. The beam bottom and sides will butt up against the column sheathing, and the ¼-in. clearance will allow for the give in the beam forms. Another method is to increase the opening by the thickness of the beam sides and bottom and to nail 2-by 2-in. cleats all around flush with the opening, as illustrated in Fig. 192*b*. In this case, the beam forms are fitted into the openings, resting on the cleats at the bottom and on the column panel.

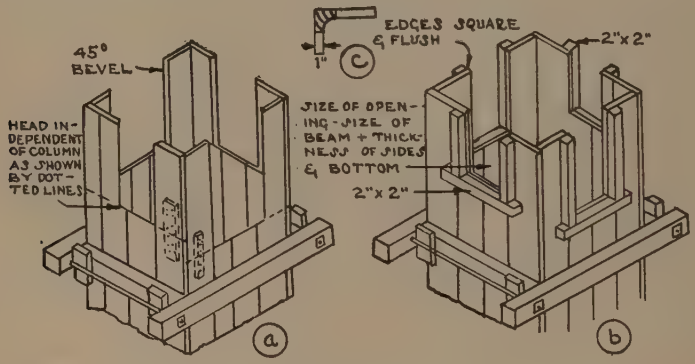


Fig. 192.—Square column form construction.

It is sometimes advantageous, as previously mentioned, to form the head of the column as a separate unit. All column panels are then sawed off at the bottom of the beams which frame into them. The head of the column extending from the bottom of the beam to the underside of the slab is then framed separately and cleated to the main column sheathing, as indicated by dotted lines in Fig. 192*a*. This method has decided advantages in stripping, as the cleats are knocked off and the head remains in place while the panels are stripped; ease of stripping and allowance for give in the forms are the two most important considerations. During stripping, sharp corners are easily broken; it is, therefore, always advisable to use a triangular double strip in the corners. If a better appearance is desired, a cove molding can be built into the forms, as in Fig. 192*c*, to provide a rounded corner in the concrete. These moldings should be nailed to the side panels and not to the end panels of the column forms.

Erection of Column Forms.—It is good practice to assemble and bolt up panels at the place where they are to be set up, if they are not too

heavy and clumsy to handle as a single unit. This method saves labor and some bracing that would be necessary if each panel were put up separately; but it can be used only when lighter forms are being employed. The reinforcing steel should also be built up into a unit and then lowered from above into the column form. The forms may be tightened by hardwood wedges which should be 2 by 4's about 6 in. in length, driven in between the yokes and the bolts, after the form is erected and the bolts are tightened.

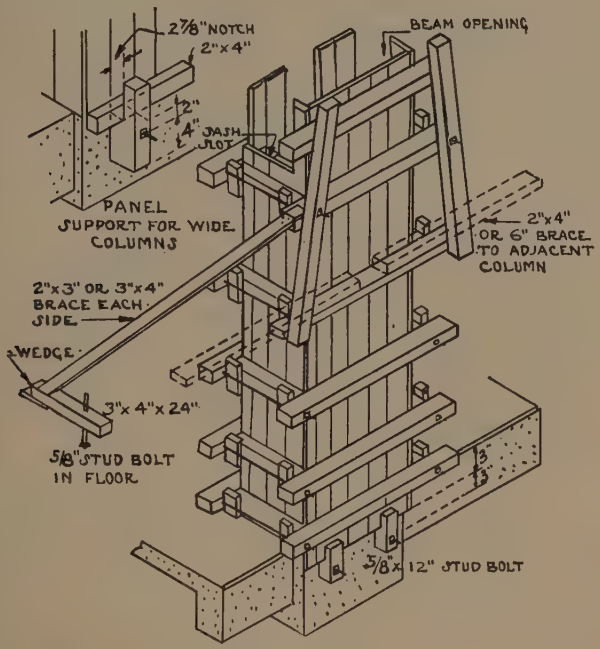


FIG. 193.—Rectangular wall column form.

Altering the Height of Forms.—If necessary to increase the height of a column form, it should be done at the bottom, since a closer spacing of yokes will be required here on account of the greater pressure, and since changing the head of the column when it is part of the form is avoided.

Where such an extension is to be used, the joint in the sheathing should have the first extension yoke placed over it at the bottom of the panels. By means of the yoke bolts, vertical 3 by 4's can be bolted across the splice, covering four yokes, two to each side, for additional stiffness. If the height of the column form is to be lessened, the form can be cut off at the bottom, and a yoke added about 4 in. from the lower edge.

Exterior Column Forms.—In an exterior rectangular column form the outside panel will overhang the column beneath it, and the entire form will require strong bracing, to prevent tipping, as shown in Fig. 193. The

outside panel at the bottom should overlap the column under it by at least 3 in. and at the top should come up flush with the top of the floor slab. The inside panel will be the same as that for an interior column. The wall beams will frame into the two end panels; the sheathing should go to the top of the slab.

As the outside panel will be the first erected and will project beyond the edge of the slab, it will require bolting at the bottom for support. Stud bolts, $\frac{5}{8}$ in. in diameter and 12-in. in length with nuts on the embedded ends, should be set about 6 in. below the top of the under column, when the concrete is poured. A piece of 4 by 4 in. about a foot long, having a notch running down the inside to about 3 in. below the column top, should be slipped over each bolt. The depth of the notch will be $\frac{1}{8}$ in. less than the thickness of the column sheathing. When the

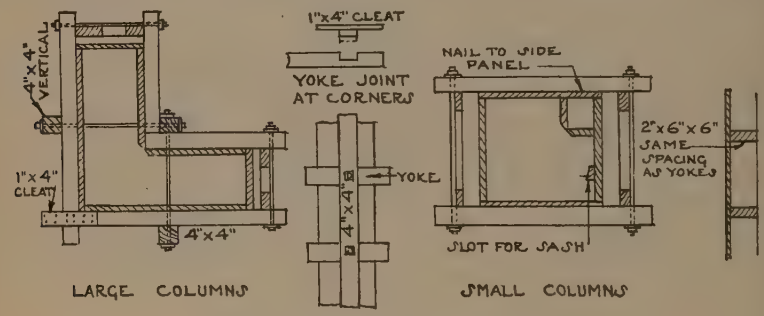


FIG. 194.—L-shaped column form.

outside panels are slipped into these notches, the 4- by 4-in. pieces are drawn tightly against the concrete, and the bolts secured.

Figure 193 illustrates this method of supporting the outside column panel and indicates, also, a method of bracing the top of the panel with a diagonal piece running from the column yoke down to a wooden block, stud-bolted to the floor. Note, also, the method of bracing the outside of the column head by means of 4- by 4-in. vertical pieces, bolted at the centers with yoke bolts and cantilevered to hold the yoke at the top of column, there being no yoke to bolt to on the opposite face of the column, because of the beam opening.

L-shaped Columns.—L-shaped columns, as shown in Fig. 194, are usually corner columns; and unless the difference in width between the long and short sides is more than a foot, a square column form with sides equal to the long side may be built up, and the L blocked out in one of the angles. The corner piece is built by nailing the sheathing to 2-in. lumber, spaced the same distance apart as the yokes and fastened to one of the side panels. If the corner columns are very large, the yokes on the two long and two short sides should be notched over each other at the corners, the long sides overlapping, with a short piece of 1 by 4 in. nailed

over the joint. Yokes are bolted in the usual way, with one or two extra bolts, if necessary. These bolts should pass through vertical 4 by 4 in. or 6 in. outside the yokes, to give stiffness to the form; one of them should be at the inside corner. The panels are supported and braced as in rectangular columns, but on two faces instead of one.

Octagonal Columns.—In constructing an octagonal form, four panels are made up for a square column. The sheathing is only 4 in. wider than the side of the octagon, but at each side yoke the sheathing is blocked out with spacers as shown in Fig. 195, to make the total width equal the diameter of the column, plus twice the thickness of the sheathing. This gives a bearing for the end yokes. The other four sides are simple boards of the required width having the sides beveled at 45 deg. The loose sides are nailed in place at the yokes, just tightly enough to hold them. The side of an octagon is 0.414 times the diameter.

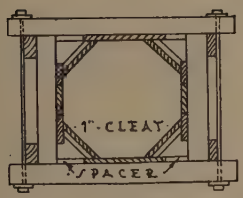


FIG. 195.—Octagonal column form.

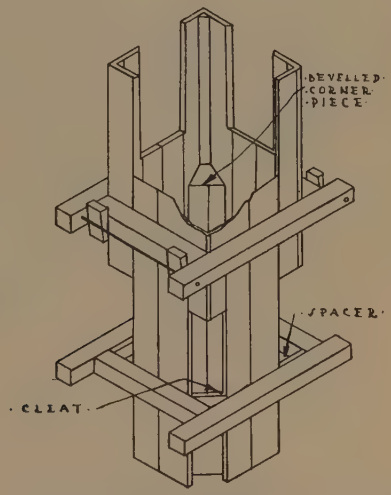


FIG. 196.—Octagonal column form with square head.

If the form is reduced for use on a smaller column, it should be done by cutting a strip from one edge of the loose sides and from both ends of the end-panel yokes and lessening the width of the spacers.

In case the head is square, it should be sheathed as for a square column, and the four corners filled in with pieces of sheathing, or with solid, fitted pieces, as shown in Fig. 196.

Beam-and-girder Forms.—In large buildings it is best to build these forms so that the entire beam or girder bottom may be handled as a unit, unless it is long; 16 ft. is probably the limit of what can be easily handled.

The sides, also, are built up in panel units, and if plans have been drawn in advance, these units may be built at the bench rather than at the point of erection, thus avoiding delay in operations.

These units should be carefully marked for identification, in order that they may be assembled and erected without difficulty. If cranes or other handling devices are available, the entire beam or girder form, that is, sides and bottom together, can often be built up as a single unit and erected.

STRIPPING ORDER OF BEAM-AND-GIRDER FORMS REMOVED IN SECTIONS

1. Remove the column wedges.
2. Remove column bolts.
3. Remove the column sides.
4. Remove strips holding lower edge of beam-and-girder sides.
5. Remove floor-panel purlins.
6. Remove girder sides.
7. Remove beam sides.
8. Remove slab panels.
9. When the floor has gained sufficient strength, beam-and-girder bottoms are removed with the shoring posts.

Where beam or girder forms are to be removed as one piece, they should be built of 2-in. lumber, to withstand stripping, hoisting, and re-erecting.

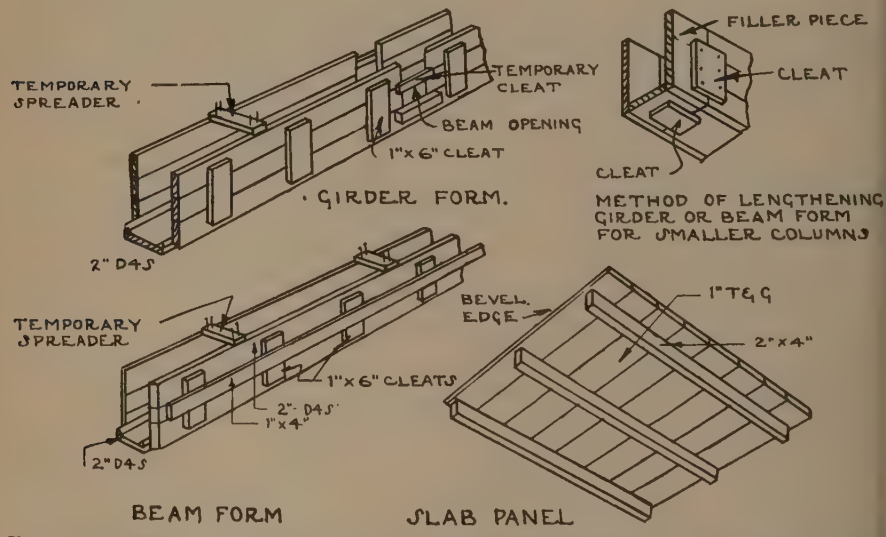


FIG. 197.—Beam-and-girder construction showing slab and beam-and-girder forms for use when the forms are removed as a unit. Figure 198 shows these forms assembled.

In these forms the main requisites are strength and rigidity. Length and size of the forms will cause but little variation in the design, as the strength and rigidity will be taken care of by the number of supporting posts.

Figure 197 shows the construction of beam, girder, and floor-slab-panel forms designed to be stripped and handled as a unit. The beams and

girders are of 2-in. stock, dressed four sides. This material should be as wide as possible, making the bottom in one piece, to avoid the necessity of cleats across the bottom, which are objectionable in handling because of the likelihood of their catching on obstructions. The beam bottom should be the width of the beam, and the sides should overlap the bottom.

The side cleats are of 1- by 6-in. material, spaced about 3 ft. apart. The sides are nailed to the bottom. Along the cleats is nailed a piece of 1 by 4 in. to support the spreaders of the floor panels. The cross-

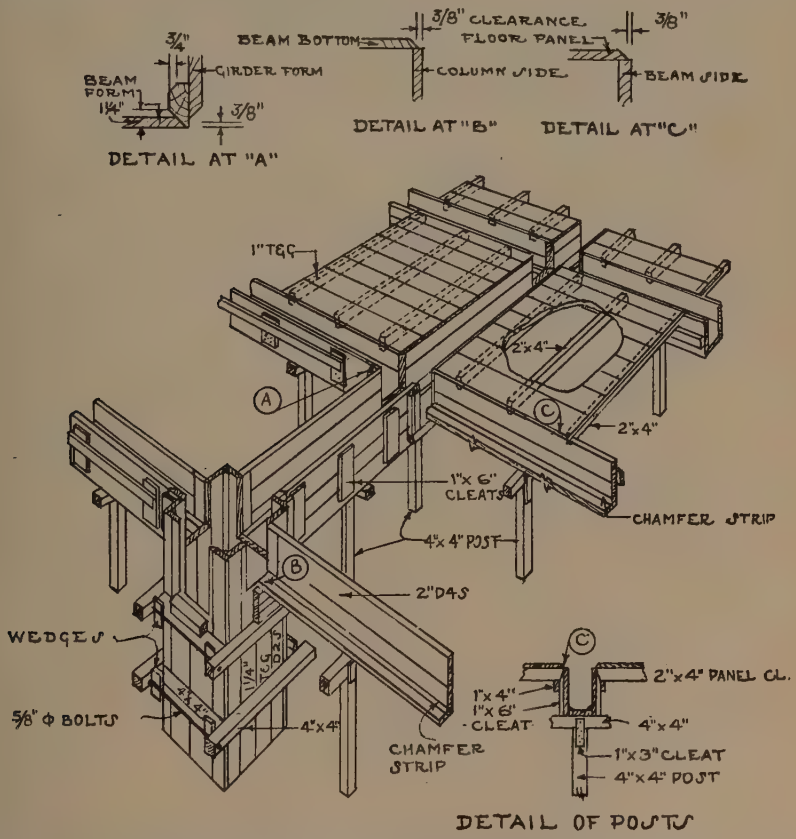


FIG. 198.—Forms for beam-and-girder floor system, showing forms which are to be completely removed as one unit.

pieces shown on top are tacked on when the form is being handled, to prevent the side from caving in.

Girder forms are the same as beam forms, except that their sides are notched to receive the beam forms. Care should be used in handling them, as they are weakened by these cuts. Temporary cleats should be nailed across the beam openings to support them while they are being handled.

Exterior beam-and-girder forms require special attention, because of the difficulty of bracing the exterior side.

Figure 198 shows the assembly of the forms illustrated in Fig. 197. The beam-and-girder forms rest on blocks on the top yokes of the columns. The ends of the beam-and-girder bottoms are flush with the

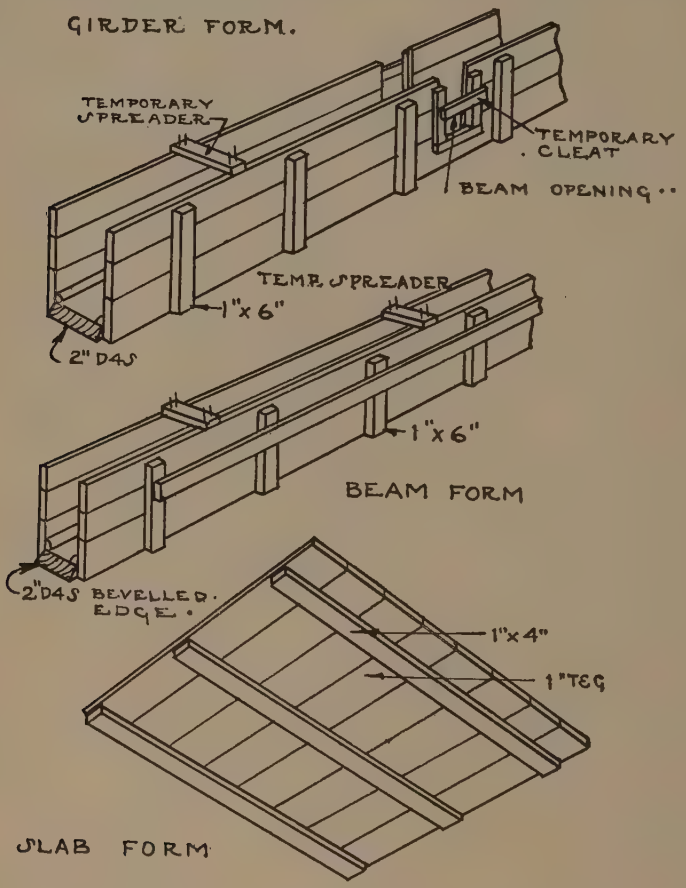


FIG. 199.—Beam-and-girder forms which are to be removed so that girder and beam bottoms remain in place on posts after sides are removed.

column forms. The end of each side of the girder or beam forms is made of a separate piece, so that it can be removed easily and thus facilitate stripping. As the columns are smaller in the upper floors, these loose pieces are employed to lengthen out the beam-and-girder forms, as shown in detail in Fig. 197.

The connection of the beam and girder is shown in Fig. 198, at *A*. The beam bottom is flush with the exterior of the girder side and rests on a cleat nailed on the girder side. The beam sides are beveled to receive a

piece of 2 by 4 in. chamfered on two edges. Note the detail *B*, which shows the bottom connection.

Attention is especially called to the details *A*, *B*, and *C*, which show the clearance necessary for the proper stripping of the forms. These clearances allow for the slight movement of the forms which has already been discussed.

STRIPPING ORDER OF BEAM-AND-GIRDER FORMS WHICH ARE REMOVED AS A UNIT

1. Remove column wedges.
2. Remove the column bolts.

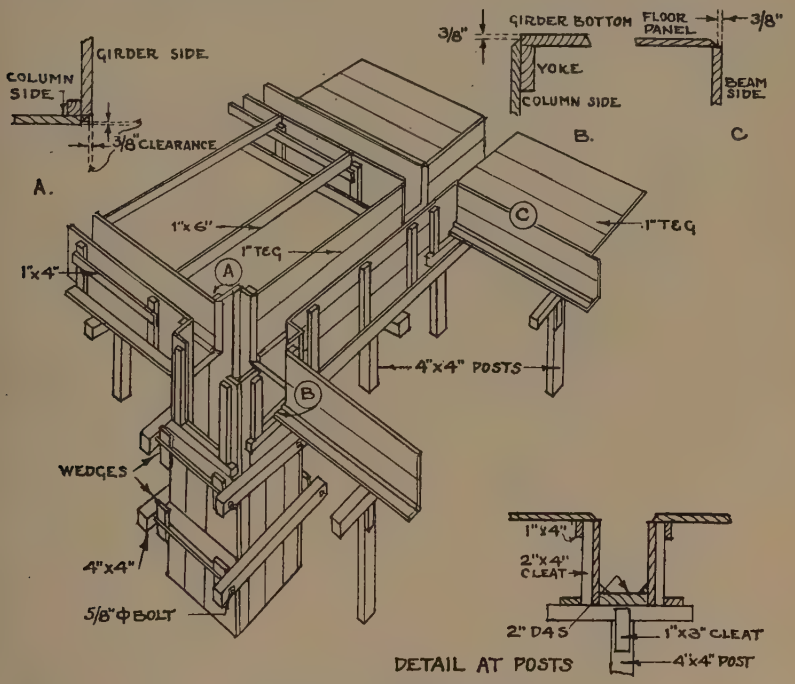


FIG. 200.—Forms for beam-and-girder floor assembled (see Fig. 199 for details).

3. Remove the blocking under the ends of the beams and girders, including cleats under beam forms at the connection with the girder.
4. Remove the key pieces at the connections of the beams and girders to columns, and at connection of the beams to the girders.
5. Remove the column sides. The removal of the key pieces allows sufficient room for the upper end of the column to slide by the beam or girder until it is free.
6. Remove the shoring under the girders, and remove the girder forms in one piece. Reshore the girders.
7. Remove the floor panels.

In Figs. 199 and 200 is shown a type of form for beam-and-girder construction that varies from that shown in Figs. 197 and 198 in that the

beam- and girder-bottoms are left in place until it is time to remove the shores. Also, loose purlins are used to support the floor panels.

Note, also, that the details of the connections of the beams, girders, and columns are different.

The beam-and-girder bottoms are of 2-in. material, dressed four sides, while the sides are of lighter material, usually 1-in. tongue-and-groove sheathing.

The beam-and-girder sides are held tight to the bottom by continuous strips nailed to the heads of the posts.

The girder bottoms will rest on caps about 4 by 4 in. supported by posts, spaced 4 ft., more or less, depending on load conditions. Braces may be run from the ends of the cap to the post, as was illustrated in Fig. 160.

The side panels, with cleats as shown in Fig. 200, should be nailed to the sides of the girder bottom, and should be held in place at the top by temporary cleats.

Two very similar methods of connecting girders to columns are shown in Fig. 160. In the lower girder, the sides and bottom lap over and rest upon the column sheathing, with edges beveled and cut ¼ in. short at each end, so that, with expansion, the ends will not be embedded in the concrete of the column.

In the upper girder, the sides and bottom run up to the outside of the column sheathing but do not overlap it. The bottom rests on a cleat or column yoke and must be cut accurately to the correct length.

Beveled fillers are used between the girder ends, sides, and column sheathing, as illustrated. Beam sides and bottom should frame into the girders, in the same way that the girders frame into the columns.

Slab Forms.—The slab forms should rest on the sides of the beams and girders, and on the joists, which are spaced, usually, at approximately 30-in. intervals and are flush with the top of the beams. The joists may be supported on ledger boards nailed to cleats on the side of the beam forms. In Fig. 160 are shown two methods of supporting joists; the one described above is illustrated at the lower beam; and at the upper beam, blocks are nailed to the beam sides, at intervals. This latter method saves material by utilizing waste pieces which have been sawed off, and allows easy removal of the joists.

Posts or Shores.—Posts or shores placed under beams and girders at necessary points should be cut off square at the ends and should always be wedged up, usually on sills, as Fig. 160 shows; this provides a simple means of taking down the posts.

They should be arranged to come over the shores of the story underneath and be set without hard driving to avoid damaging the concrete which has not acquired its final set.

A camber of ¼ in. in every 10 ft. is advisable in all beams and columns, to provide against settling.

Wall Forms.—Wall forms are usually built of 1- or 1¼-in. horizontal sheathing, with vertical studs nailed at intervals, which depend upon the allowable span of the sheathing, height of the wall, rate of pouring, and size of studs.

For high walls, horizontal waling pieces are generally used, to strengthen the wall. Figure 201 shows diagonal braces, wedged against

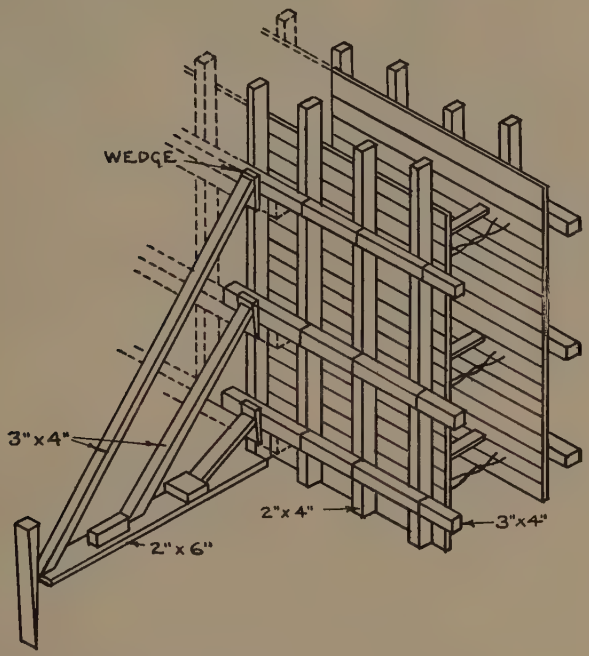


FIG. 201.—Method of holding wall forms in place; using wales and diagonal braces.

the wales and blocked against a sill on the ground, run out from the wall to stiffen the forms. Figure 168 shows the use of double studs without waling pieces. Note the separators between the double studs, which do not have to be bored for bolt holes. Figure 202 shows difficult form work in a building erected in Seattle, Washington. Figure 203 shows the wall forms for the Los Angeles, California, Produce Market Building. Double waling strips, with bolts between, are used in this construction. Figure 204 shows a typical wall assembly and accompanying pouring schedule. Here, too, double waling pieces are used, which saves the cost of buying dimension timbers and only slightly increases the labor cost.

Miscellaneous Forms.—Typical form work for stairways having a midway landing is illustrated in Fig. 205. A good method of insuring

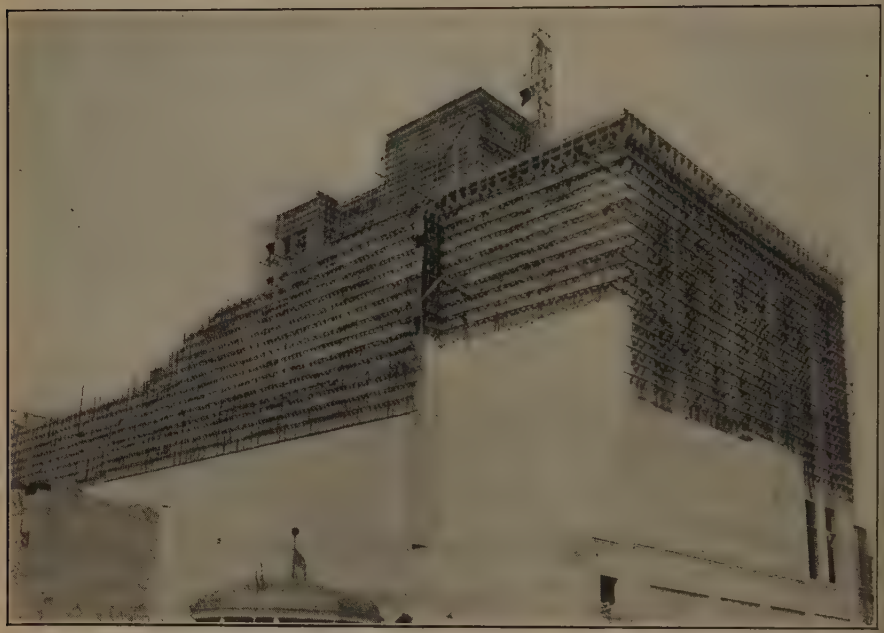


FIG. 202.—Form work for monolithic concrete walls.

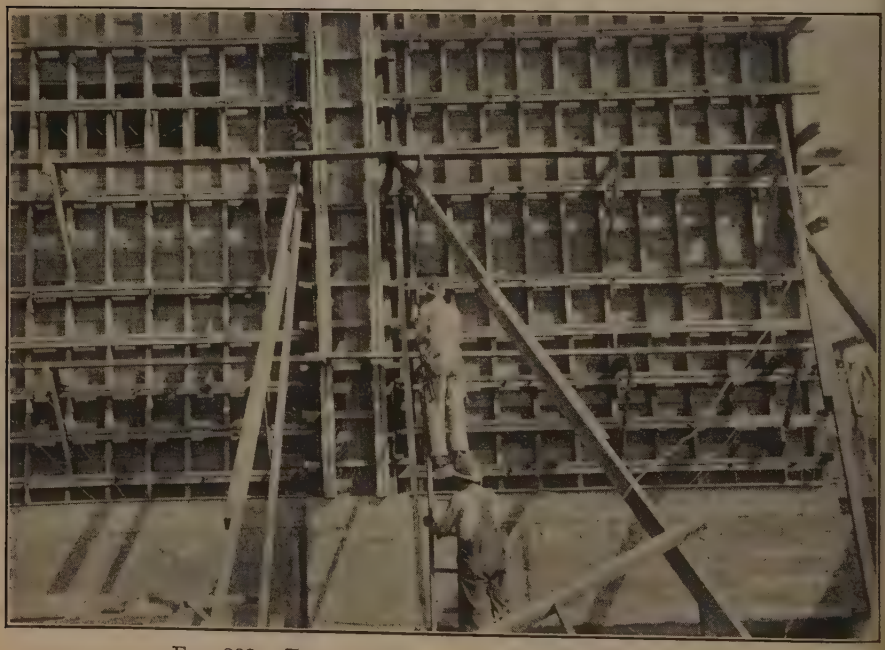
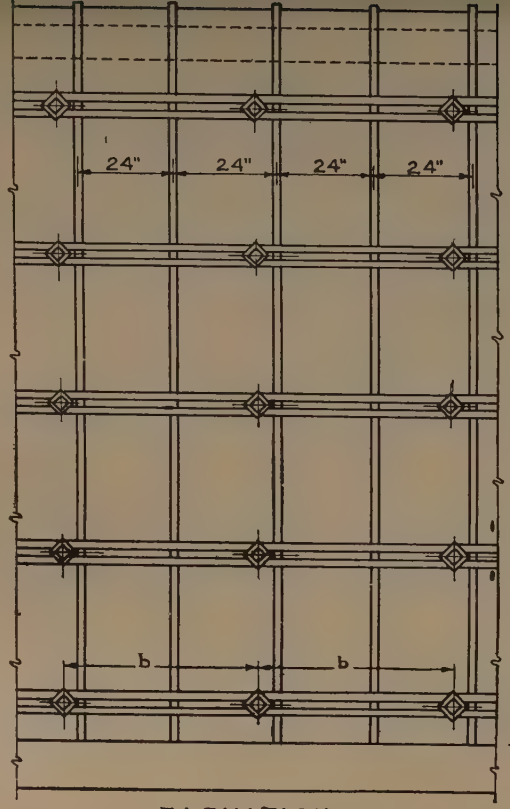
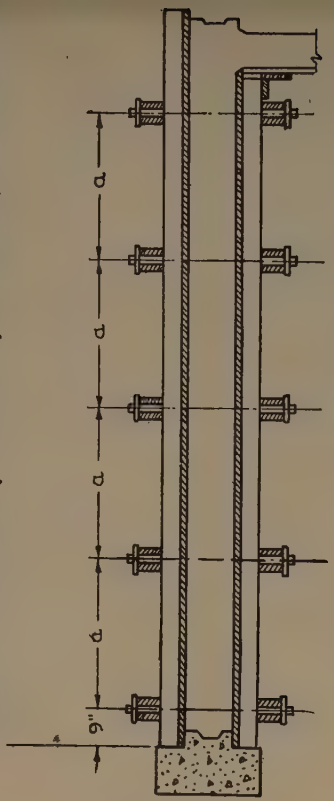


FIG. 203.—Form work for monolithic concrete walls.



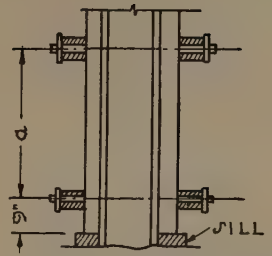
· ELEVATION ·



· SECTION ON CONCRETE BASE

POURING SCHEDULE		
FT. PER ½HR	a	b
2" - 0"	3'-0"	4'-2"
3' - 0"	2'-6"	3'-8"
4' - 0"	2'-2"	3'-4"
5' - 0"	24"	3'-2"
6' - 0"	22"	3'-1"
7' - 0"	20"	3'-0"
8' - 0"	18"	2'-10"
10' - 0"	17"	2'-8"

SCHEDULE APPLYING TO WALLS WITH 3"x4" STUDS AND 2"x 6" STANDARDS



· SECTION WHERE POURING IS MADE DIRECTLY ON FILL

FIG. 204.—Typical wall assembly and pouring schedule.

that each step receive its full portion of concrete is to have the carpenter follow along as each step is poured. One-half of the tread form is nailed in place. As the concrete fills up the step, the carpenter should nail the other half of the tread into place. A laborer tamps it down just before the step is closed up by the carpenter.

If stairs are built between two walls, they should be supported by bearings on shoulders built into the wall. The sheathing will be the same

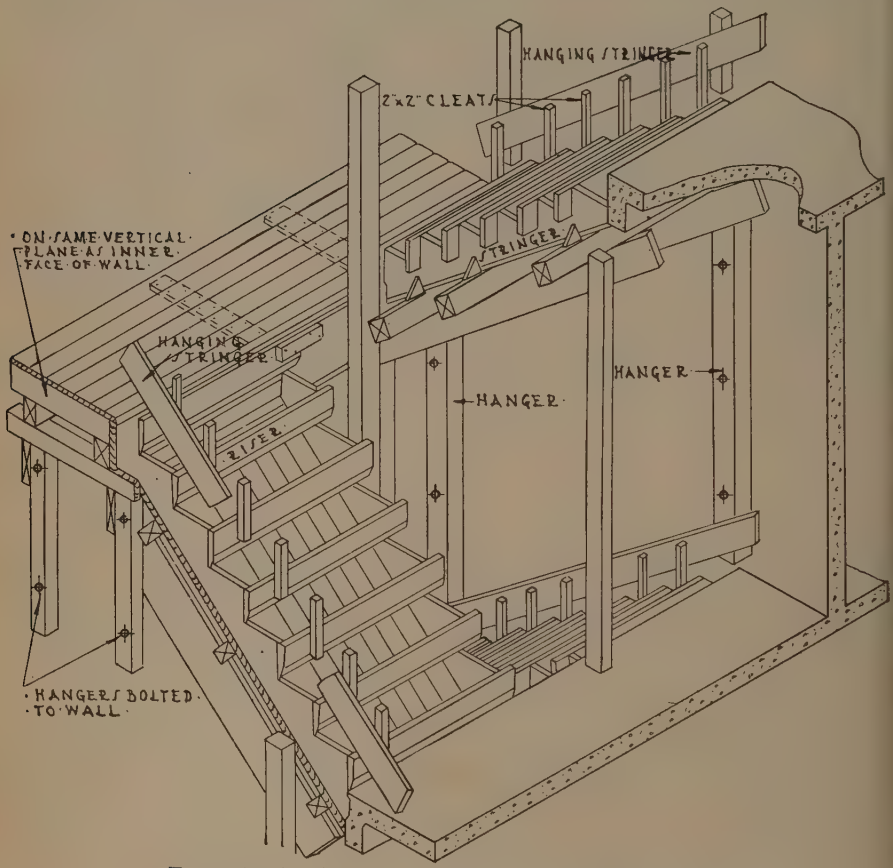


Fig. 205.—Typical form work for stairway construction.

as for other stairs; supported by posts wedged underneath. The risers must be cut to full width between the walls. They may be fastened to 2- by 4-in. strips running vertically up to a plank sloping parallel to the stairs and at least 3 in. above the top of the risers, for clearance. Details of this construction are shown in Fig. 206.

Cornice details differ with each design. The method of shoring the cornice is an important feature, since most of the weight to be supported will be outside the building wall. When a heavy, elaborate cor-

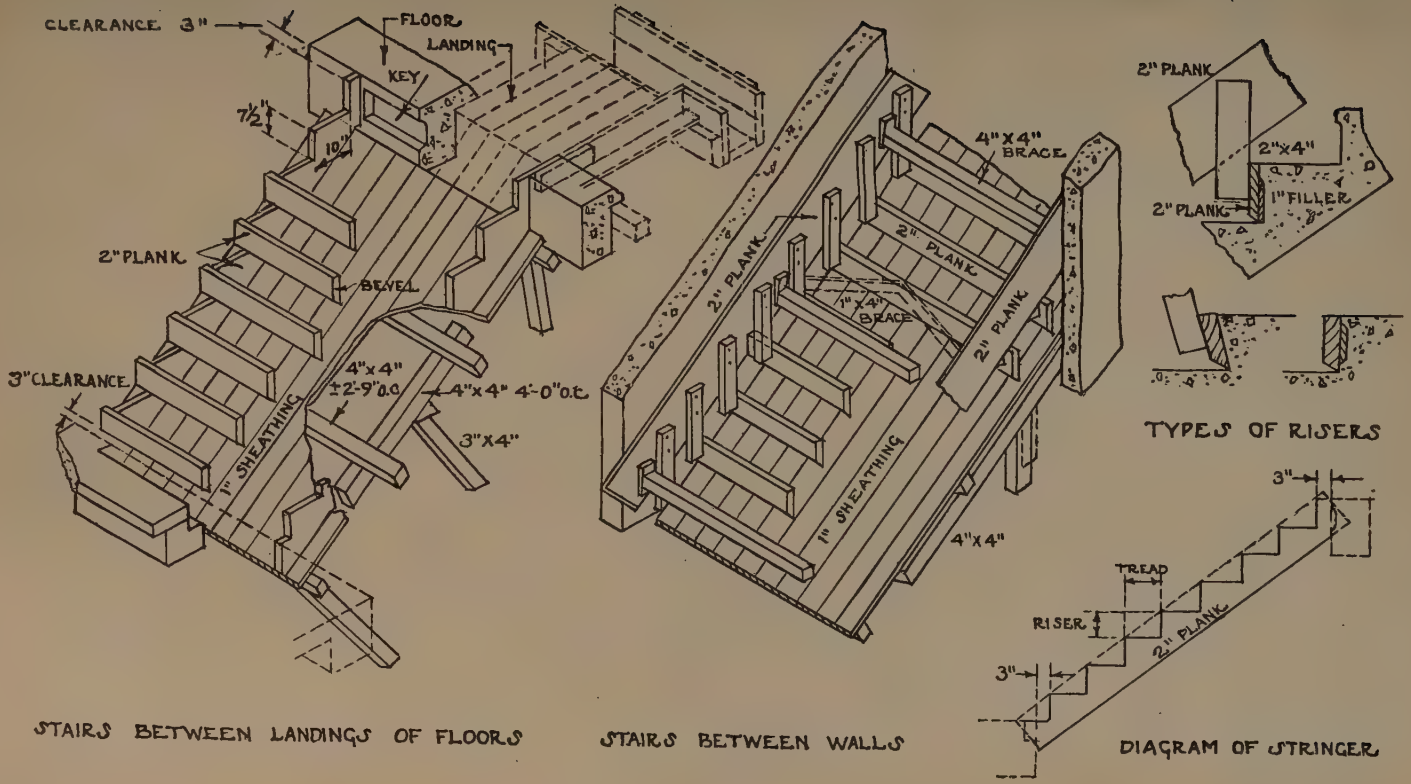


FIG. 206.—Stairway forms.

nice is to be built, it should be kept separate from the roof slab, in order to avoid any delay in pouring the slab; the wall beams should be keyed to receive it.

Cornice forms are usually expensive to construct, for which reason they should be built as short as practicable and re-used over the length of the cornice.

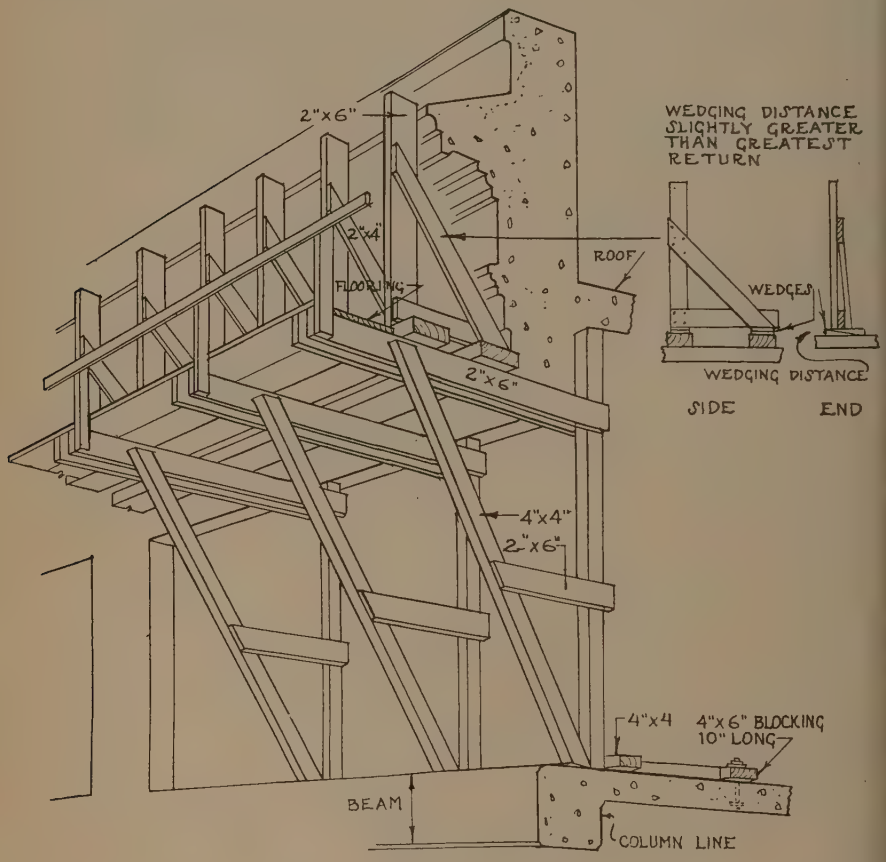


Fig. 207.—Supports for cornice forms.

There are many ways of building up shores and braces for cornice forms. Figure 207 shows a typical design. Note the detailed elevation of caps, wedges, and bracing on which the necessary sheathing and molding, or templates to form the face of cornice, are placed. Interesting details are the use of the blocking at the foot of the posts to take the thrust, and the bolts in the top floor to hold blocking in place.

The tops of the cornice forms are often tied to the roof slab by means of wires attached to bolts left in the roof at the time it was poured.

Three other uses of forms are shown in Figs. 208, 209, and 210—namely, sill forms, upturned beam forms, and roof or sloping slab forms.

Erection of Forms.—In ordinary large buildings, column footings and columns should be accurately spotted, preferably by the use of a transit. After two corner columns have been set first, to give the line, forms for

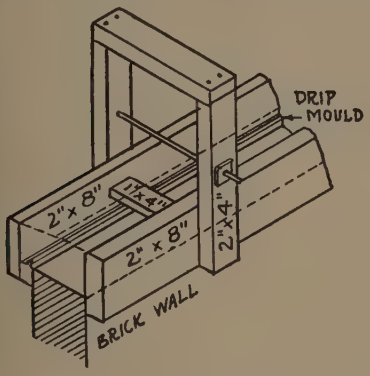


FIG. 208.—Sill form.

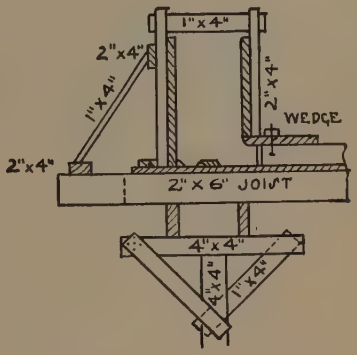


FIG. 209.—Upturned beam form.

wall columns and connecting beam bottoms can be placed. The first interior row of columns and the placing of the girder bottoms from these to the outside column follow in logical order. After this come the shores, girder sides, beam bottoms, shores between the girders, beam sides, edgers, joists, and, finally, the slab panels. The last operation is to

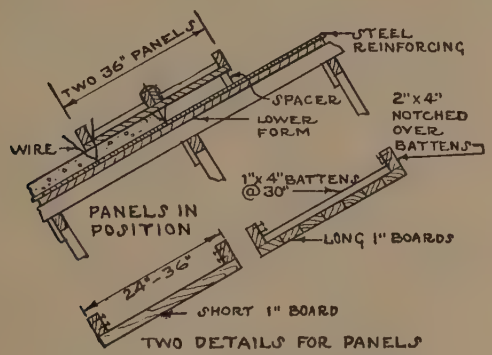


FIG. 210.—Roof or sloping slab forms.

cross-brace the shores. Before commencing to pour, wedges should be tightened and the columns inspected and cleaned through the opening in the side at the bottom of the column. The entire assembly should be checked to insure clean forms free from wooden blocks and débris, and particular attention should be given wedges under shores to be sure that

they are tight. During concreting, a carpenter should watch constantly to keep the wedges tight and to warn the foreman of any movement.

Stripping.—The proper time for stripping the forms depends on so many factors that definite rules are apt to be misleading when applied to particular cases.

The character of the concrete, the temperature and moisture conditions, and the location and kind of forms to be stripped all influence the proper time for removal.

The really safe rule, therefore, is to let the engineer in charge make the decision, for he will be guided by other considerations, such as the length of the span, the stresses in the member, and similar facts, as well as by his own experience.

Various stripping schedules are used, of which the following is fairly typical:

AIR TEMPERATURE

Member	60°	50° to 60°	40° to 50°	Under 40°
Columns and bearing walls (provided girders are shored to prevent appreciable load reaching column)	2 days	5 days	10 days	Stripping should be done only after conference with the engineering department
Beams and girder sides	.....	with slabs		
Slabs[1] (spans up to 6 ft.)	3 days	8 days	14 days	
Beam-and-girder bottoms (spans under 15 ft.)	12 days	21 days	28 days	
Flat slabs	12 days	21 days	28 days	

[1] Add 1 day for each additional 2 ft.

A schedule in use by some builders for warm-weather stripping is as follows:

BEAM-AND-GIRDER CONSTRUCTION

1. Columns: 24 hours after slab is placed.
2. Girders: 60 hours after concreting (third day).
3. Beams: 84 hours after concreting (fourth day).
4. Panels: after beams are removed.

FLAT-SLAB CONSTRUCTION

1. Columns: 24 hours after slab is poured.
2. Drop heads: 36 hours after concreting (second day).
3. Slabs: 84 hours after concreting (fourth day).

These periods are all minimum, to be used where forms are needed for re-use and where a certain schedule has been planned for the entire

building. The longer the forms can be left in place the safer and better the concrete work.

Many builders have test prisms, poured at the same time and under the same conditions that obtain when the concreting is done. The prisms are tested for strength and hardness, and the results are useful as a guide though not to be depended on completely.

Serious failures have occurred in concrete structures because of too early stripping or improper reshoring.

Forms should be so constructed that beam-and-girder sides can be removed without disturbing the bottoms or the several necessary permanent shores. Only one beam should be stripped and reposted at a time. Additional reshores can be added after the stripping, if necessary, to carry the green concrete safely.

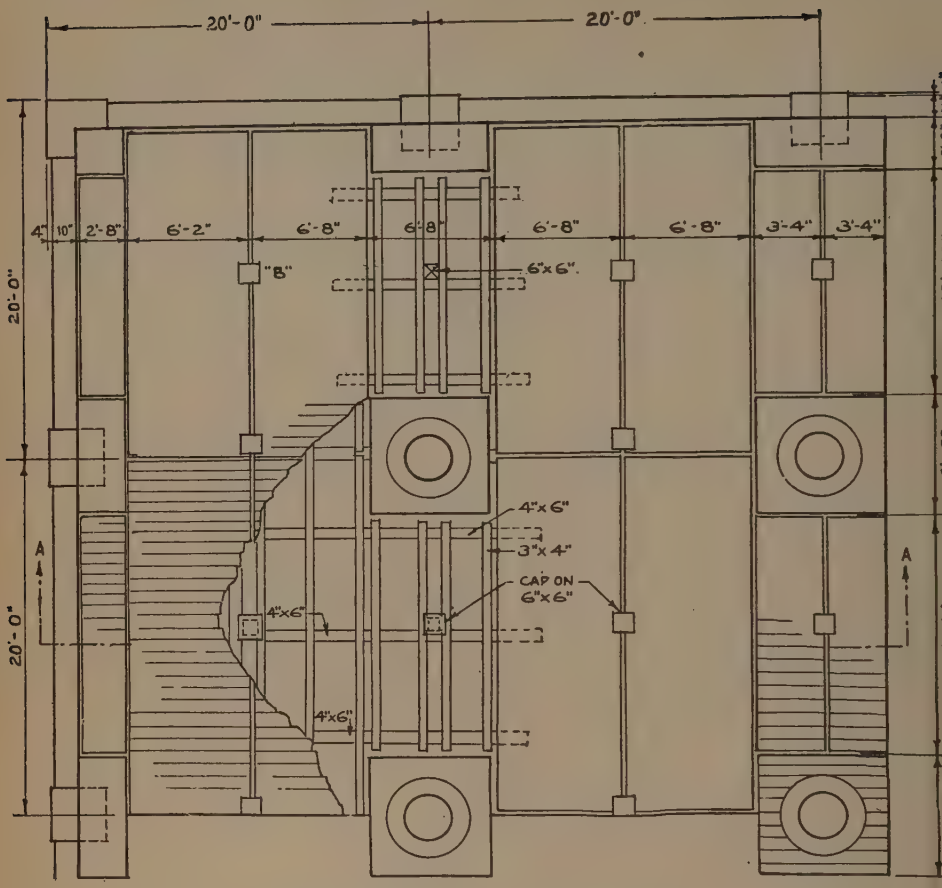
Similarly, flat-slab forms should be so constructed that at least three permanent shores can remain in place in each bay for about 3 weeks and still permit the stripping of the slab forms.

Figure 211 shows a system used for bays from 17 to 23 ft. between the columns; the dimensions are for a 20-ft. panel but are shown only as a general guide in locating shores. The detail at *B* shows the proper position of and method for framing over permanent shores, which are all 6 by 6 in. here; 4- by 6-in. blocks are bolted to opposite sides of the shore near the top. The 4- by 6-in. joists are wedged up over these blocks to the proper height to serve as a bearing for the 3- by 4-in. stringers of the built-up floor panels. These floor-panel boards are fitted around the shore so as to leave a 12-in. square space, which is filled by a cap, 1 in. thick, independent of the floor slab and resting on the shore at the same height as the sheathing.

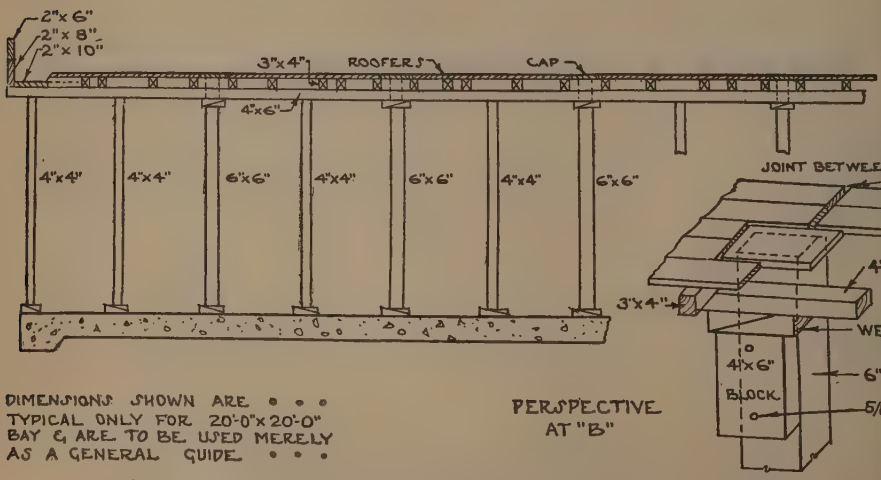
With this construction the floor-slab forms are easily removed, leaving the shores in place, with a 12-in. square bearing area on the underside of the concrete floor. This will adequately take care of the floor just concreted. It is, however, necessary at times to carry some of the load from upper floors, in which case additional shores must be added. Frequently, the dead load of the story above is placed on concrete only a week old, which has developed only a part of its ultimate strength. To take care of such a condition successfully, it is necessary to have the two lower stories fully reshored, in addition to the shores under the forms, and to have the third lower story at least partially reshored.

This means that in the flat-slab work shown in Fig. 211, two stories, exclusive of forms, would have all the 6- by 6-in. shores in place, and the next lower story would still have the 6- by 6-in. shores left in at the center of the bays.

It should be borne in mind that the general rules just stated are for warm-weather concreting. In cold weather the setting time of concrete is much more uncertain. For this reason, it is imperative that forms be



PLAN FOR BAYS 17'-0"-23'-0" INC.



DIMENSIONS SHOWN ARE • • • TYPICAL ONLY FOR 20'-0"x20'-0" BAY & ARE TO BE USED MERELY AS A GENERAL GUIDE • • •

PERSPECTIVE AT "B"

FIG. 211.—Arrangement of permanent shores, flat-slab construction.

kept in place as long as conditions on the job permit. At least one extra story should be reshored at such times, and the same rule applies if the work is being done at high speed.

Where different sections of a building are being poured, here and there, because of special conditions, it is important to keep a careful record of the date of each concreting operation.

It is advisable to have the concrete foreman tag each section with the date of pouring and so avoid the danger of stripping too early.

The actual stripping of forms should be done by laborers, under a competent foreman. The employment of carpenters for this work is usually uneconomical.

Care should be taken not to chip the green concrete and not to pry against it with bars.

Built-up units should be preserved as such. Boards, joists, and like members should not be allowed to fall to the floor but should be eased down by rope slings on horses or frames to avoid breakage. Small cleats, wedges, etc., should be lightly nailed to their own units to prevent loss.

Cleaning Forms.—Cleaning the forms as soon as possible after they have been removed is important, since the concrete adhering to them will harden if left too long. If they are well oiled or soaped when clean, the concrete will not adhere to them so readily when they are used again.

Precautions for Plastering Over Concrete.—Where the concrete surface is to be plastered, forms should not be oiled or soaped, as the grease will weaken the bond between the plaster and concrete. Undressed boards should be used to give the concrete a rough surface. To get the necessary adhesion, a special, patented bonding plaster should be used.

CENTERING AND FALSEWORK

Timber falsework is used to support masonry arches and steel bridges during erection, until the permanent structure has set and become strong enough or is near enough to completion to support its own weight.

That part of the falsework which is used to support the concrete of the masonry arch rib, or barrel, is known as the *centering* and should be of the simplest possible design and made with due regard to the labor involved both in erection and in striking. The best design for an arch will keep the cost of labor and materials at a minimum, will admit of a high percentage of salvaging, will be of a sufficient strength, stiffness, and rigidity, and will allow for striking without undue shock to the concrete.

Centering.—There are numbers of different types of arch centering which may be used, but the one which has proved to be most economical for medium-sized arches (unless some special condition at the site makes truss centering more desirable) is the trestle centering or bent design, wherein the sheathing and stringers are supported on transverse caps, which are, in turn, held up from the ground by posts or piles.

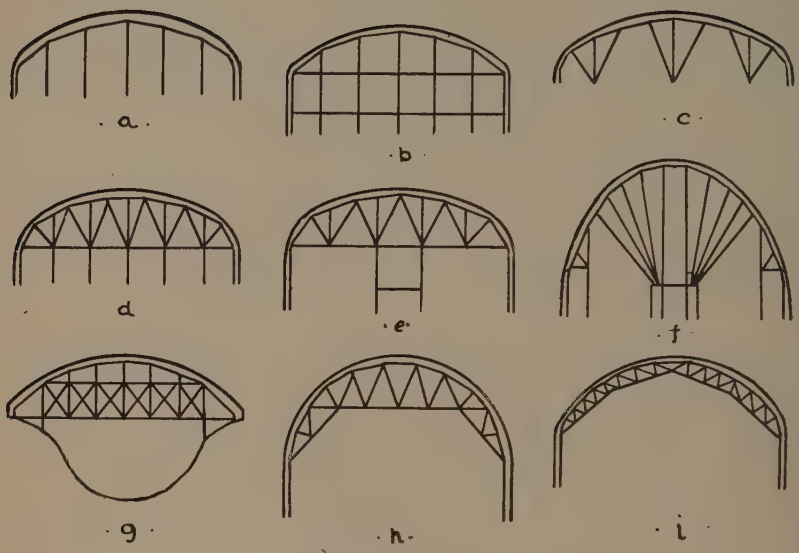


FIG. 212.—Types of arch centering.

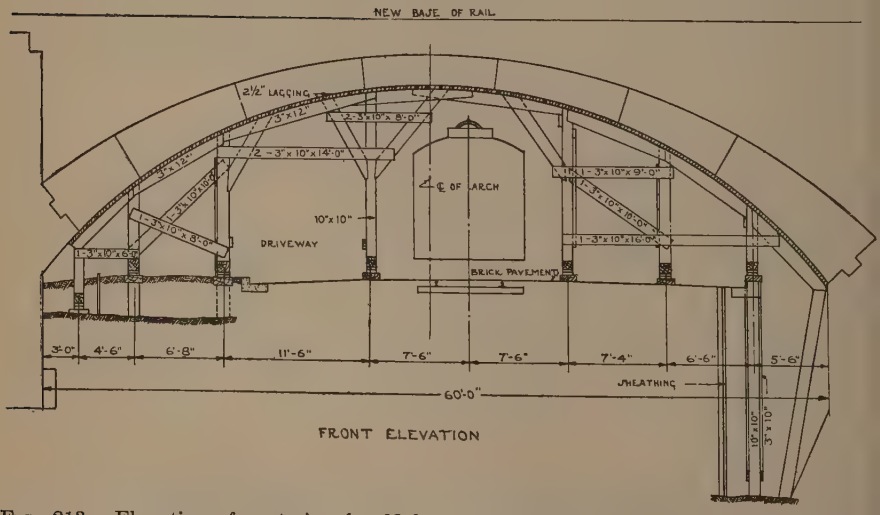


FIG. 213.—Elevation of centering for 60-ft. arch, wood posts wedged up on wood sills.

Figures 212, *a* to *g*, show skeleton outlines of centers which are frequently used. Detail marked *c* is used where foundations are difficult because of water, sand, and the like, and where it is desired to use as few foundations as possible. The posts may be inclined, and several of them supported by each footing.

Selection of the kind of foundation to use for posts and a decision as to whether piles would serve better depend on soil conditions at the site of the bridge, and should be settled by the engineer in charge after careful examination.

In water, or over a wet soil, piling is generally necessary. But where the water is shallow and the river bed is rock or hardpan, posts are usually framed on sills set directly on the river bed.

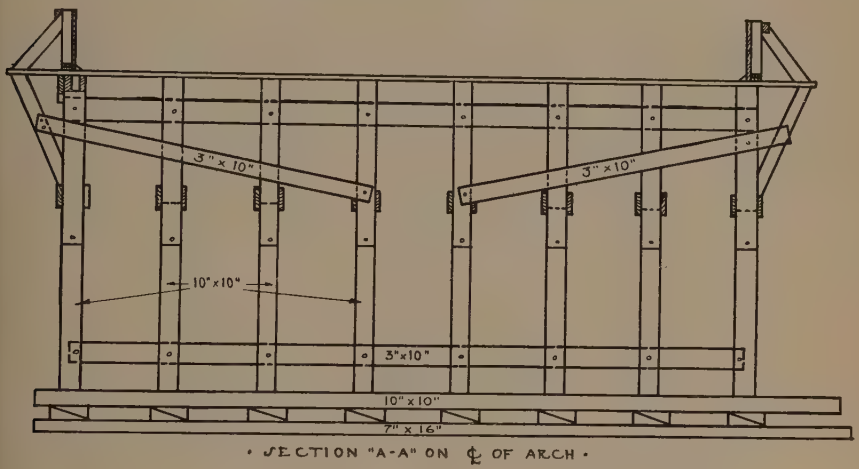


FIG. 214.—Cross-section of centering for 60-ft. arch shown in Fig. 213

The various parts to design are the lagging, stringers, sheathing, caps, and posts. It is customary to space stringers uniformly in the different panels and to allow for a decrease in loading by varying the spans.

Timbers of a size sufficient to keep the panel spans within approximately 8 to 14 ft. should be used.

In designing arch centers, provision must be made for horizontal as well as for vertical forces. Sufficient camber must be given centers to allow for the deflection due to live load, dead load, and settlement during concreting.

Special attention should be given to the method and sequence of pouring the different sections of the arch. At certain stages of the work, upward forces are generated, and it often becomes advisable to pour the crown first, or immediately after the haunches have been concreted. The upward forces will be counteracted if the arch ring is poured in longitudinal sections equal in length to about one and one-half times the

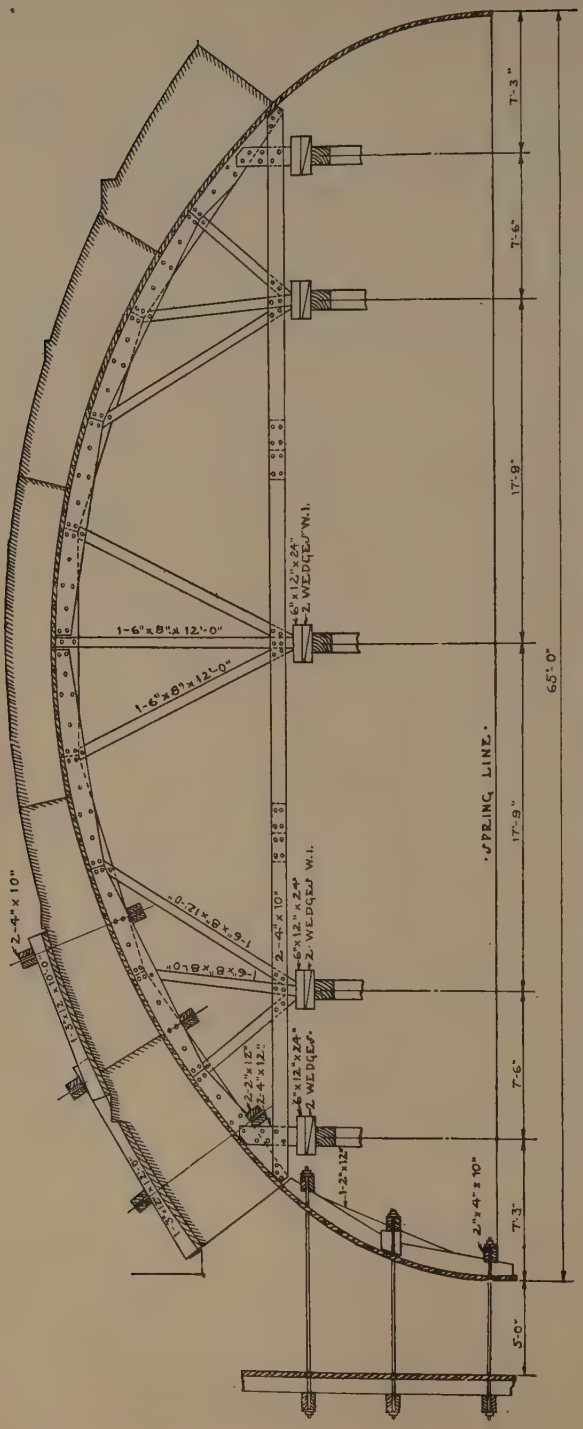


FIG. 215.—Arch centering for two-span bridge combining truss and fan-shaped bracing.

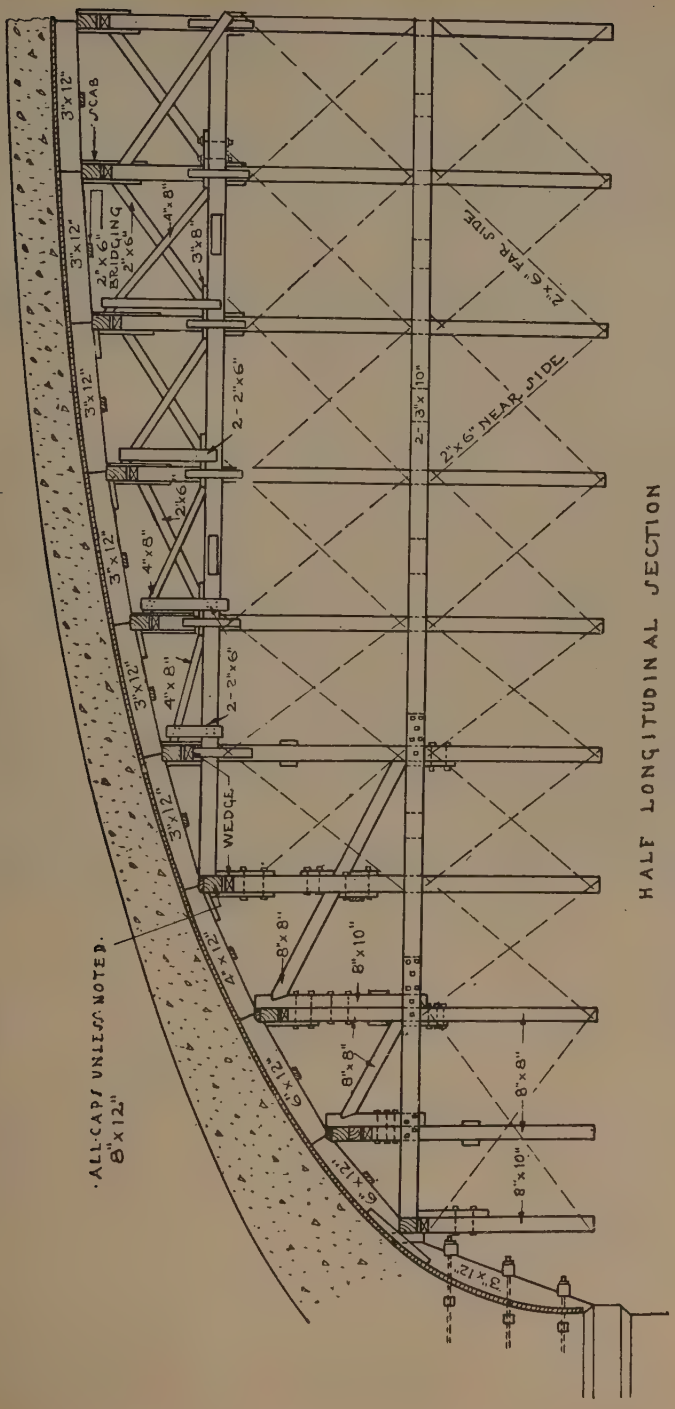


FIG. 216.—Built-up centering for concrete arch bridge, 129-ft. span.

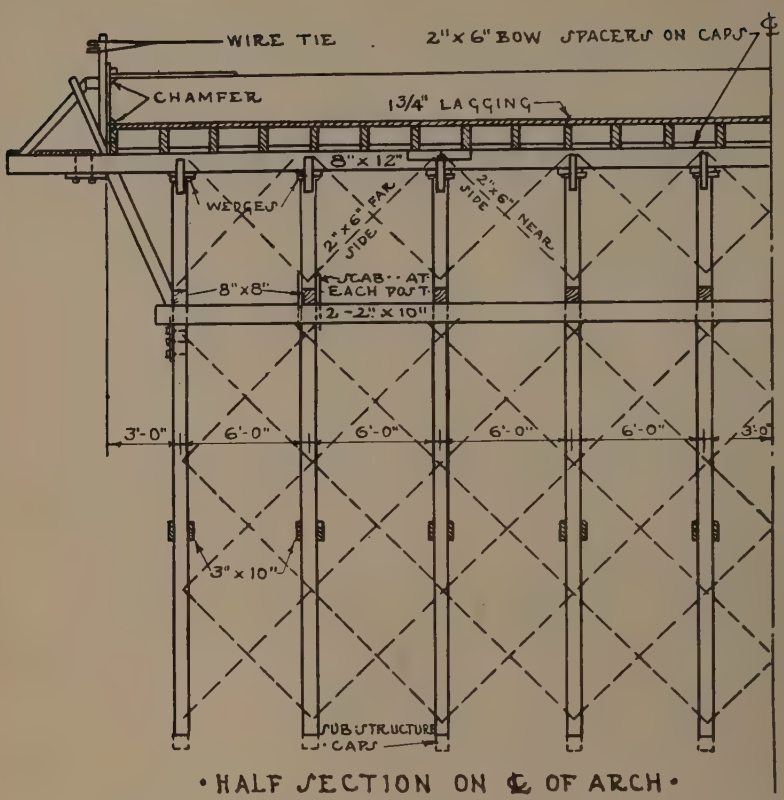


FIG. 217.—Cross-section of arch centering shown in Fig. 216.

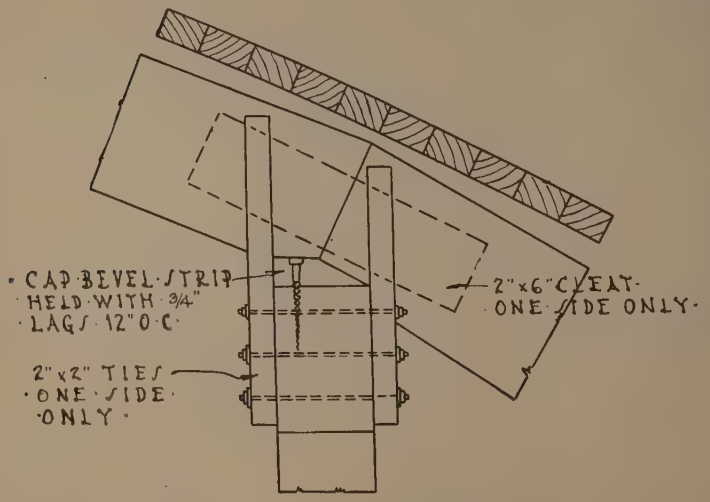


FIG. 218.—Detail of bow joint under lagging. See Fig. 216.

thickness of the arch ring. These sections should be poured symmetrically with respect to the center of the arch and alternatively across the width of the arch, usually starting at the crown. This procedure practically eliminates the effect of any settlement which may occur and, to a considerable extent, relieves the arch of drying stresses.

Where a bridge consists of a series of arches, an unbalanced thrust occurs during concreting and must be taken up either by the piers or by the substructure of the centering. As centering is a temporary affair, it can be designed for higher stresses than would be permissible in a permanent structure; but deflection must also be investigated by the engineer before a decision is made regarding the size of timbers to be used.

FIG. 219.—Ashtabula viaduct.

To facilitate the stripping and removal of the arch forms, a generous use of hardwood wedges is advisable. They should be carefully designed and placed, for when they are removed the weight of the arch ring will cause a slight deflection, while, at the same moment, the centering, relieved of its load, will rise. It is well to consider designing a concrete bridge so that stock sizes of lumber can be used in the centering.

Figures 213 and 214 show centering for a 60-ft. arch over River Street, Kankakee, Illinois, where 10- by 10-in. posts wedged up on wood sills were used throughout. The posts near abutments were carried down to rock, while the other bents were supported by a brick pavement.

Figure 215 shows another type of centering, on the C.B. & Q. Railroad, used for a two-span bridge over the east branch of the Fox River. Here, a combination truss and fan-shaped bracing on capped piling was used. The lagging was 3-by 6-in. tongue-and-groove material. Piles were

driven on 3. ft 6-in. centers. All the stringers for the 26 trusses were of 4-in. lumber cut from templates; white-oak wedges were used over pile caps and under brace sills.

The bolts extending through concrete arches to hold lagging in place should be well oiled and within 12 hours after concreting should be given a half turn, to insure easy withdrawal.

FIG. 220.—Ashtabula viaduct.

Figures 216 and 217 show built-up centering used on several span of 129 ft. each in a concrete arch bridge; the posts rest on substructur caps, as indicated. A detail of the stringer or bow joint under the laggin is shown in Fig. 218.

Figures 219, 220, and 221 show a viaduct built as a federal aid project a Ashtabula, Ohio, and recently completed. This bridge has seven rein forced-concrete arches, 121 ft. long between piers, and six girder spans each having 39 ft. clear length. The total length of the viaduct, includ

ing the piers, is 1,200 ft. The roadway width is 32 ft., with a 5½-ft. walk on either side. The height of the roadway above the river bed is 67 ft.

In Fig. 219, the forms for the bottom of the ribs are in place, while, in Fig. 221, one completed span is shown with forms in place for the ribs to be poured.

Figures 222*a*, *b* and *c* show the form work used for a highway bridge in Monroe County, Indiana.

In Figs. 223*a* to *e* and 224*a*, *b* and *c* are shown the arch-ring and floor-beam centering for one of the spans of the Charles River bridge on

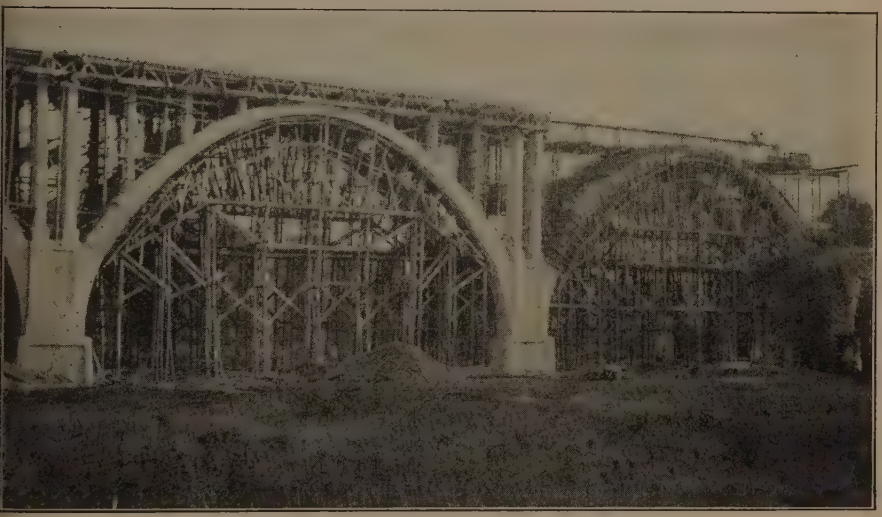
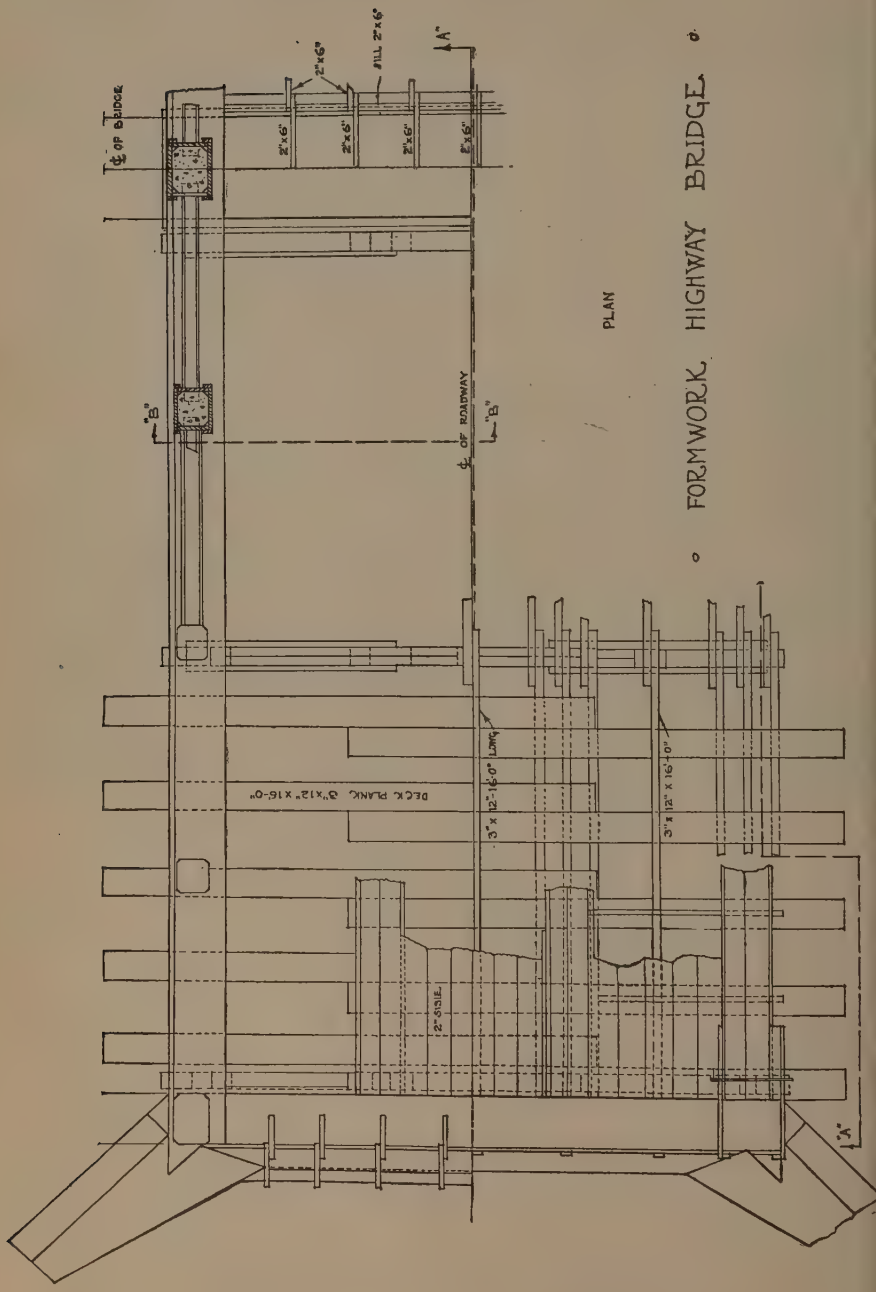


FIG. 221.—Ashtabula viaduct.

the East Cambridge extension of the Boston Elevated Railway, built in 1910. The form work and centering for this bridge were carefully planned and laid out, and accurately constructed, as was evidenced by the finished job.

The following is extracted from a paper read by C. T. Fernald, engineer in charge of this work, before the Boston Society of Civil Engineers in 1912:

In constructing the superstructure, the first step was to provide suitable supports for the falsework. A scheme was adopted providing for a pile structure of 12 to 16 bents, depending on length of spans, and so designed that the loads of the arch rings came directly down posts placed on wedges and bolsters directly over the piles. The two middle rows of piles parallel to the axis of the structure supported bents designed to carry the floor system, track stringers, and the industrial railway for carrying the concrete and supplies. The entire system of falsework was arranged to be moved forward with the progress of the work and was, in fact, used about three times in the length of the bridge.



FORMWORK HIGHWAY BRIDGE

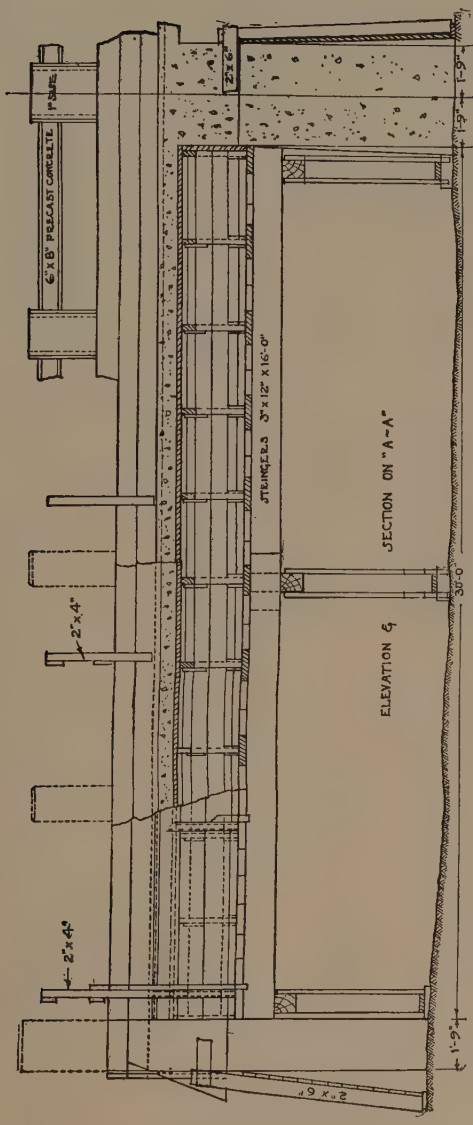


Fig. 222b.—Elevation and section of falsework and forms for highway bridge in Monroe County, Indiana. (See Fig 222a.)

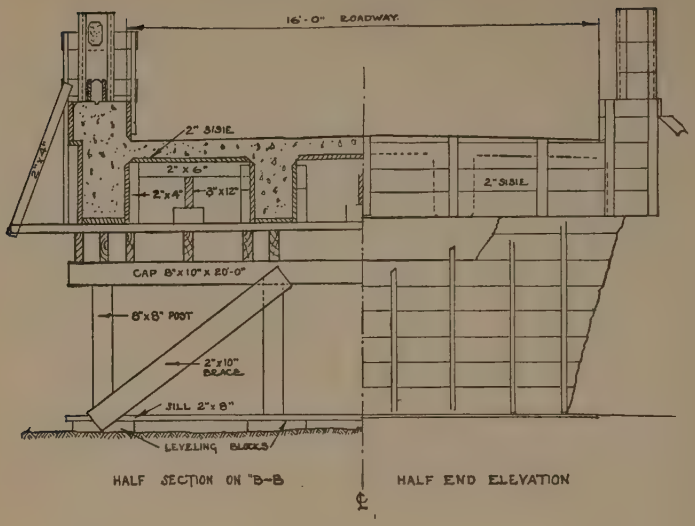

16'-0" ROADWAY.
2" SISIE.
2" x 6"
2"x4"
3"x12"
2"x6"
2" SISIE.
CAP 8"x10" x 20'-0"
8"x8" POST
2"x10" BRACE
SILL 2"x 8"
LEVELING BLOCKS
HALF SECTION ON "B-B
HALF END ELEVATION
ALL FORM LUMBER TO BE SURFACED TO A UNIFORM WIDTH & THICKNESS SISIE.
FORM LUMBER FOR PIERS, ABUTMENTS, BEAMS, FLOOR SLABS & CURBS 2" SISIE.
FORM LUMBER FOR RAILINGS MAY BE 1" SISIE.
FORMS FOR PIER & ABUTMENTS MAY BE WIRED OR BOLTED THRU THE CONCRETE
STRINGERS, CAPS AND POSTS SHALL BE OF DENSE AND STRONG YELLOW
PINE, DOUGLAS FIR, HARD MAPLE, OR WHITE OAK.

FIG. 222*c*.—Half section and half end elevation of falsework and forms for highway bridge in Monroe County, Indiana. (See Fig. 222*a*.)

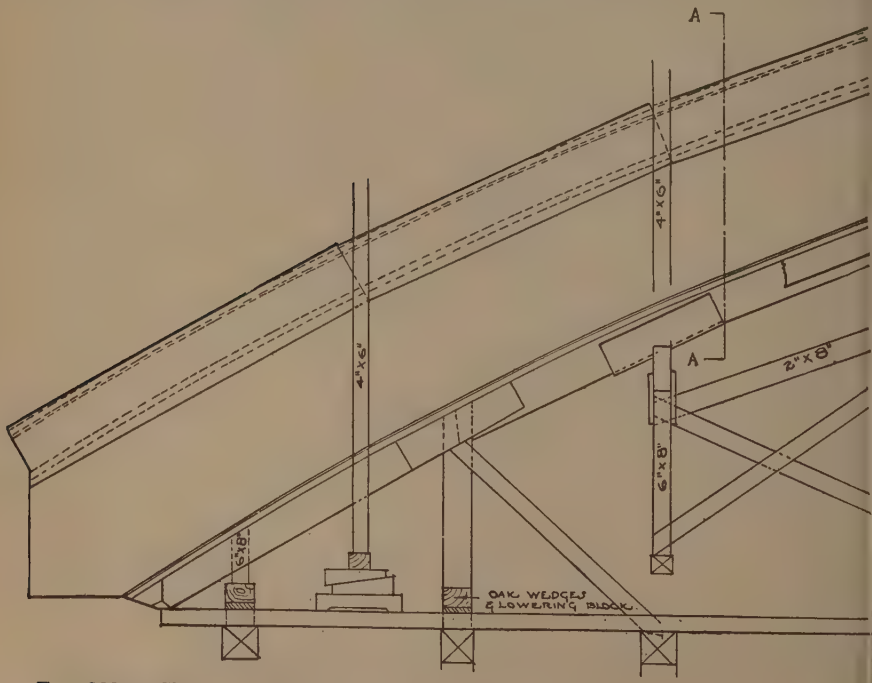


FIG. 223*a*.—Shows portion of half side elevation of arch ring centering for one of th 122 ft. spans of the Charles River Bridge—Boston Elevated Company. (See Figs. 223*c* *b* and *c*, for complete view.)

The side forms for the arch ring were built in sections about 9 ft. long, made of 2- by 6-in. spruce, with the boards set radially. The forms for the spandrels and the floor system were of spruce, made in panels and used on an average of four times.

Falsework for Steel Bridges.—The cost of falsework is an important consideration, as the work must be designed to support the weight of the steel structure until the span is completely self-sustaining. Except for

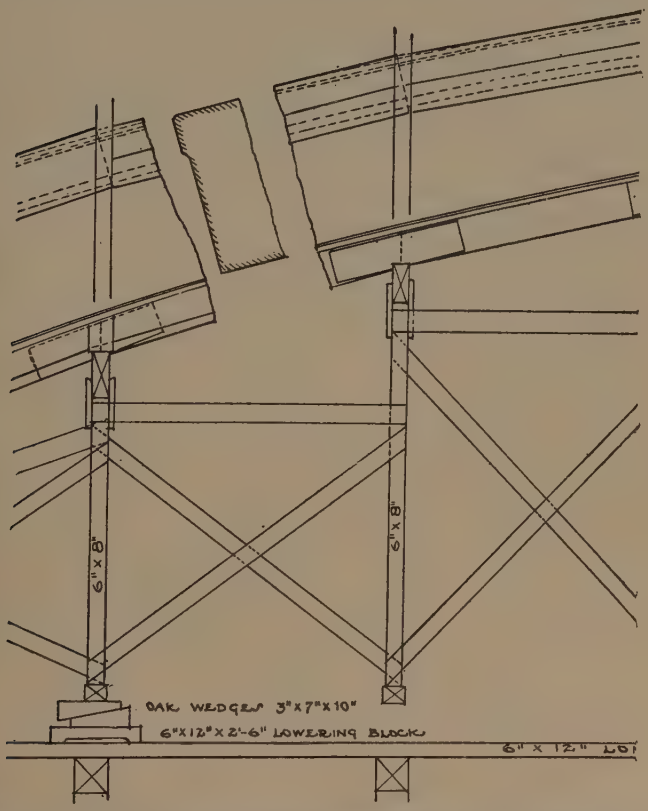


FIG. 223*b*.—Shows portion of half side elevation of arch ring centering for one of the 122 ft. spans of the Charles River Bridge—Boston Elevated Company. (See Figs. 223*a*, *b* and *c*, for complete view.)

cantilever erection, riveted and pin-connected spans are nearly always erected on falsework. Of course, short spans which can be assembled and bolted up on the ground are swung into place without the use of falsework.

The falsework supports the weight of the span until the span is completely pinned and bolted up. As the cost of falsework is a big item in the total cost of erection, several designs are often made, to minimize the amount of timber used. Whenever it is possible, members from the permanent structure are utilized temporarily in the falsework construc-

tion, as, for example, stringers to carry the track for the erecting equipment.

The falsework for spans erected over streams is usually built up on foundation bents of piling. The piles are capped and braced and support the falsework proper, which is made of sawed timbers. Sometimes,

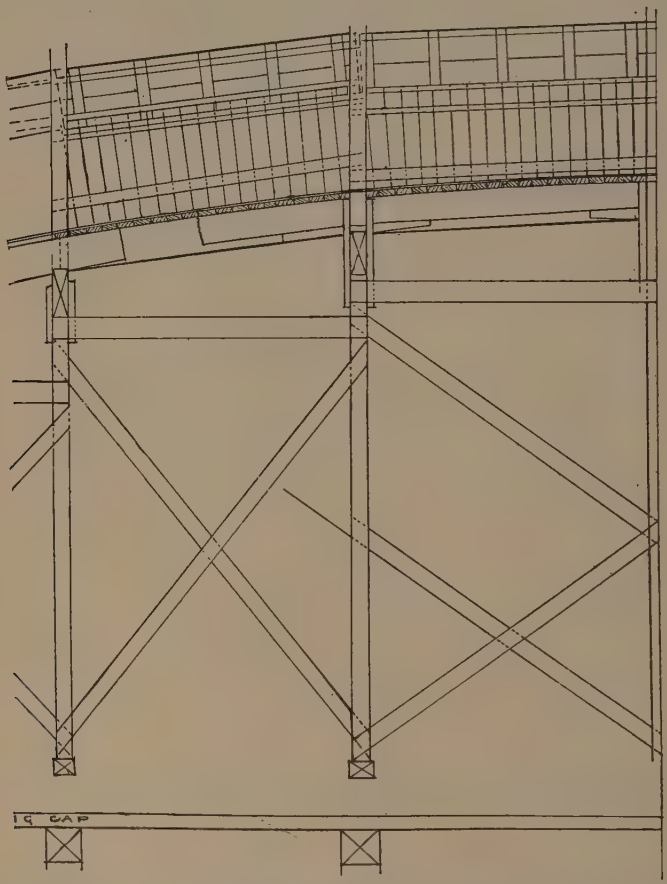


FIG. 223*c*.—Shows portion of half side elevation of arch ring centering for one of t 122 ft. spans of the Charles River Bridge—Boston Elevated Company. (See Figs. 223 *b* and *c* for complete view.)

however, when the span is not high, the piling itself constitutes t falsework.

When traffic is not maintained during erection, the falsework is co paratively light, the loads to be carried being the weight of the new sp and the erecting equipment. When traffic is maintained, there are, course, the stresses caused by the moving trains, which, however, tra at reduced speed. In maintaining traffic on deck structures, addition

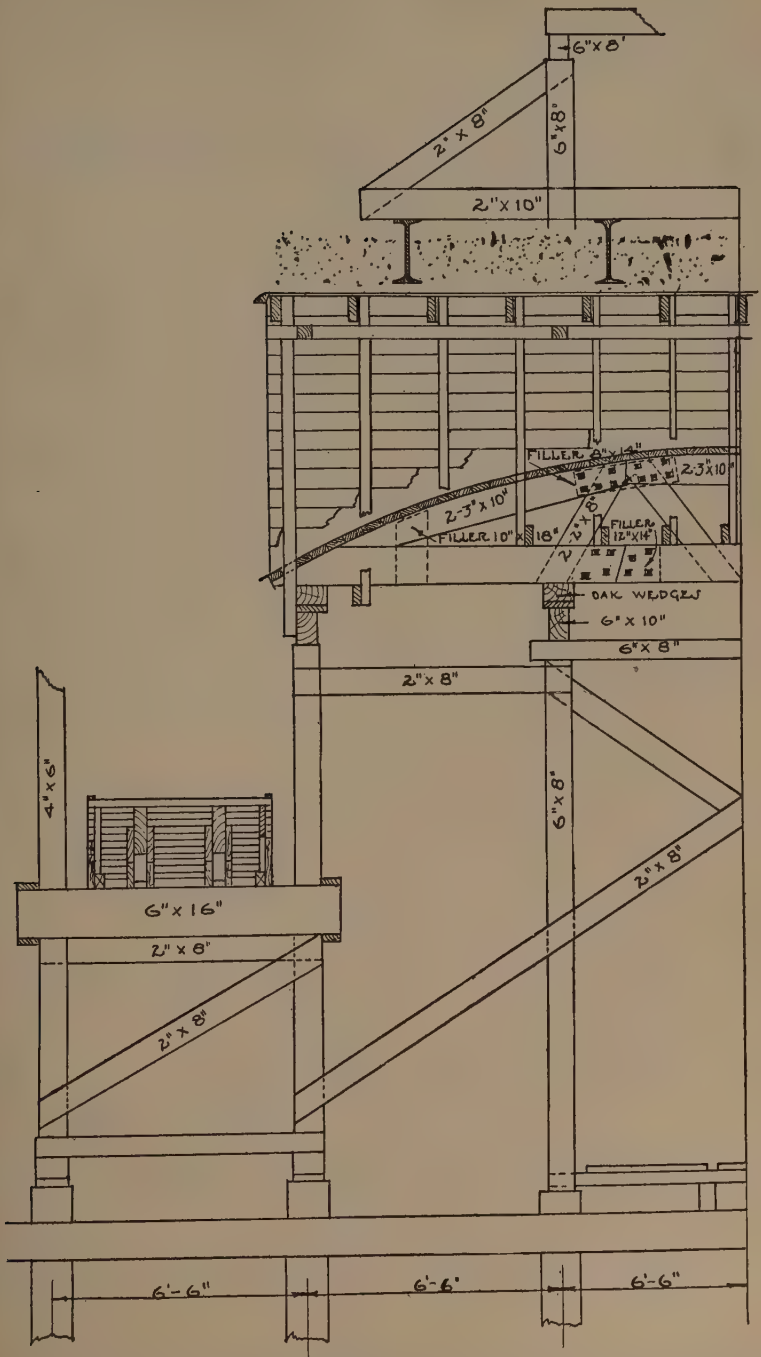


Fig. 223*d*.—Shows half section *A*-*A* (see Fig. 223*a*) including centering at floor beam "*C*." (See Fig. 224*b*.)

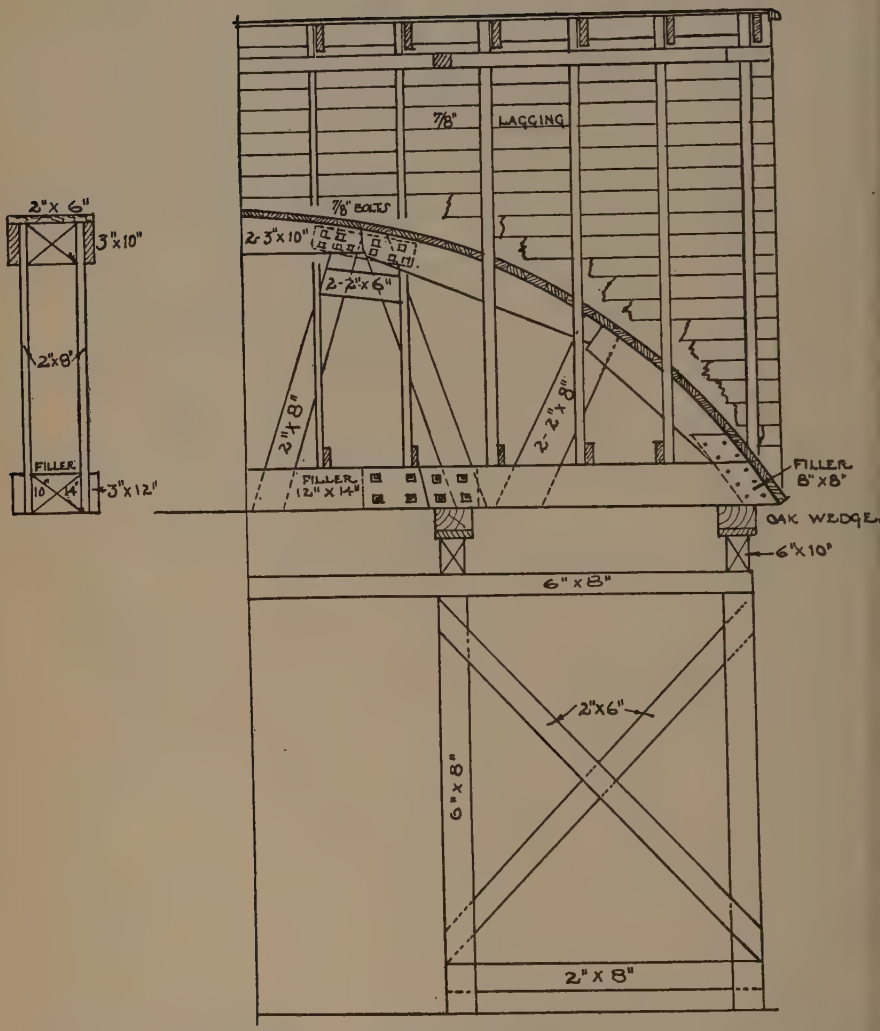


FIG. 223*e*.—Shows half section on center line of pier, including centering at floor beam "*D*.
(See Fig. 224*a*.)

falsework must be placed on top of the main falsework to bring the track to the proper elevation.

In building up falsework for the support of a simple span, a bent is placed at each panel point, and one near each abutment for the support of the end stringers. If the loads are large at the panel points, two bents are used.

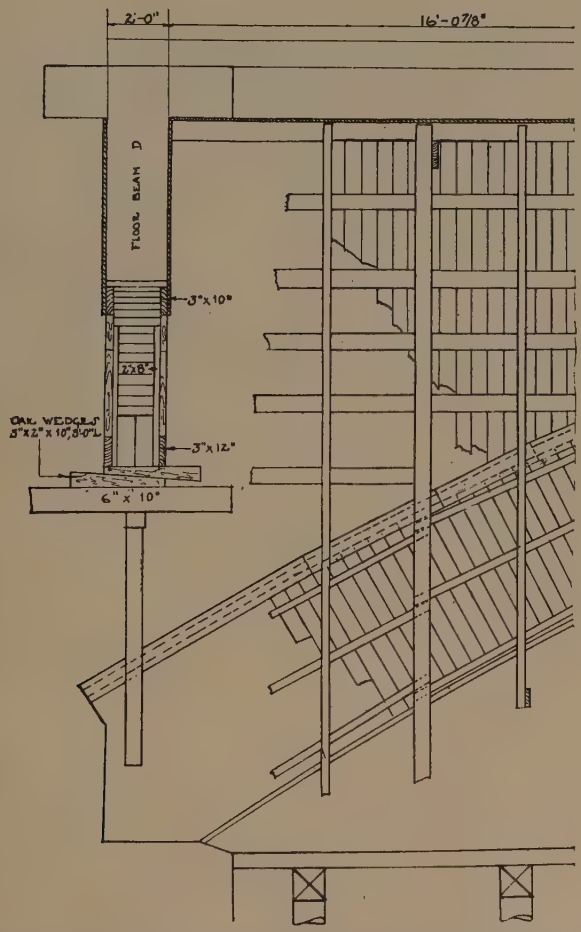


FIG. 224*a*.—Shows portion of half elevation of arch centering for interior of arch ring in the 122 ft. span of the Charles River bridge—Boston Elevated Company, illustrated in Fig. 223. (See Figs. 224*a*, *b* and *c* for complete view.)

A simple bent is made up of two battered legs, two vertical or plumb legs, a horizontal cap piece, and a lower horizontal piece or sill. More than two battered and plumb legs are often used, depending upon the load induced by the dead load of the span and erecting equipment. Falsework for a span is usually erected with a derrick car, which, with a front-truck reaction of from 150,000 to 175,000 lb., requires four or five

legs for the support of the equipment. This load, with the weight of the heaviest member erected, together with the dead load of the span, would increase the number of legs about four or five. The number of legs to be used in a bent may be determined by dividing the total reaction by the bearing power of one leg. If a 12 by 12 timber is used, assuming a

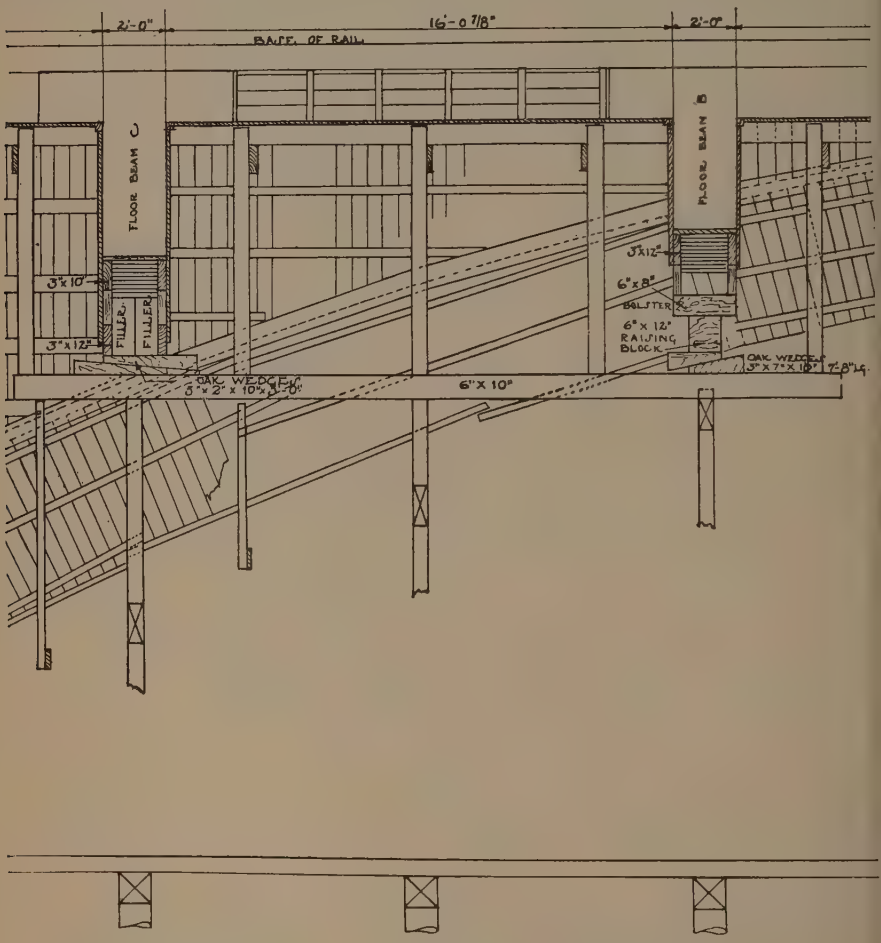


FIG. 224*b*.—Shows portion of half elevation of arch centering for interior of arch ring in the 122 ft. span of the Charles River Bridge—Boston Elevated Company—illustrated in Fig. 223. (See Figs. 224*a*, *b* and *c* for complete view.)

bearing value of 400 lb. per square inch, the load carried by each leg is about 28½ tons. The bents are braced with planks bolted to each side to give stability. Longitudinal timbers or I beams are bolted to the caps of the bents under the trusses to be erected; also, in order to support the tracks for the traveler and for the handling of material, such timbers or I beams make up the deck of the falsework. Some of the bents are

braced together longitudinally to form braced towers to give stability to the falsework. When the height of the falsework is considerable, the bents are built up in stories or tiers and properly braced. Horizontal timbers or I-beam struts (*sash* or *level bracing*) extending the entire length

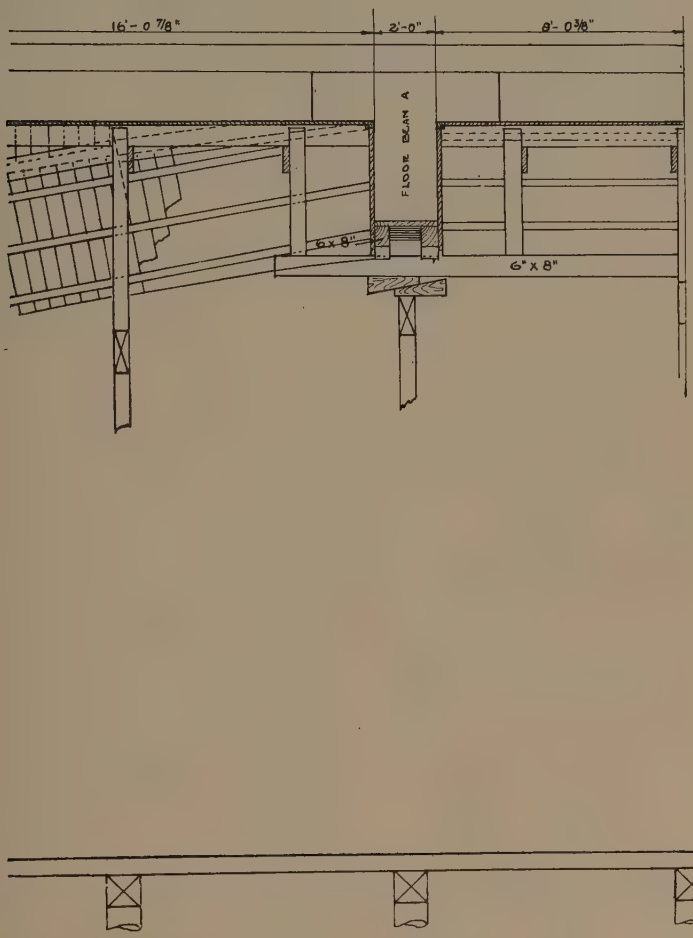


FIG. 224c.—Shows portion of half elevation of arch centering for interior of arch ring in the 122 ft. span of the Charles River bridge—Boston Elevated Company—illustrated in Fig. 223. (See Figs. 224*a*, *b* and *c* for complete view.)

of the span are bolted to the bents as required. For high falsework, the bases of the bents are spread to prevent lateral overturning.

In figuring the loads on the bents, an excess load must be provided for, to take care of the unequal settlement of the bents and stresses caused by using jacks, in case jacking is required to adjust or move the span.

The building of falsework over streams or rivers is often a matter of hazard, for high water, driftwood, or ice may wreck the entire structure.

If, moreover, a traveler is used for erection, high winds pushing against the elevated tower may endanger it.

Soil conditions should be investigated, to ascertain the necessary number of piles to be used and insure the attainment of sufficient bearing. Nearly all of the considerations which affect the erection of arch centers will also need to be taken into account for the erection of the substructure of steel-bridge falsework, excepting, of course, the thrust of the arches.

Deflection and settlement should be provided for in the design. In large bridges the live load often causes so much settlement that the deflection is negligible, but as far as possble an unyielding foundation should be provided.

Experience seems to show that if falsework material is to be used over again, the timber should be approximately as follows:

For posts and caps	12 by 12 in.
For bracing	4 by 8 in.
For sash pieces	8 by 10 in.
For stringers	8 by 16 in.

TIMBERING FOR MINES AND TUNNELS

In mine and tunnel timbering, it is necessary to support the relatively small pieces of rock which become loosened around the top and sides of the openings.

Timbering is not used to support the tremendous mass of rock and earth between the roof of the tunnel and the upper surface of the ground. This great mass goes through an adjustment or "initial creep," after the excavating is accomplished, and forms itself into a stable self-supporting arch somewhere above the roof of the excavation.

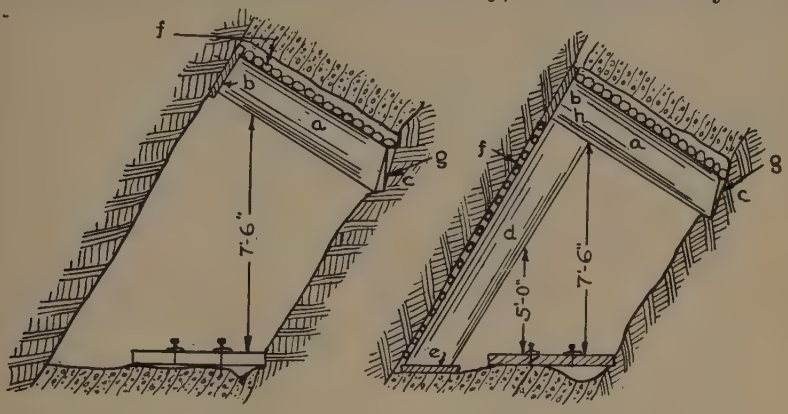
The loose material below this arch, then, constitutes the load which is to be supported by timbering, and the kind and amount of timbering necessary will depend wholly on the particular conditions at the site. Some tunnels through solid rock require almost no timbering, while tunnels or shafts through decomposed rock require heavy timbering.

The important point is that the timber be placed in time. This means immediately following the excavation, before the rock on the sides and roof of the tunnel have had time to loosen and break off during the settling and forming of the natural arch mentioned above.

In selecting material for timbering, preference should be given to local woods. Mine timbers usually serve a temporary need and are subject to early decay and attack from insects, because of the confined damp places in which the wood is necessarily used. Woods, therefore of inferior structural qualities will often serve long enough to answer the purpose.

For more permanent timbering, however, southern pine, Douglas fir spruce, oak, and chestnut are preferable. Strong, elastic woods are

desirable; brittle woods that break without warning are dangerous; and too flexible woods, such as willow and hickory, are unsatisfactory. When

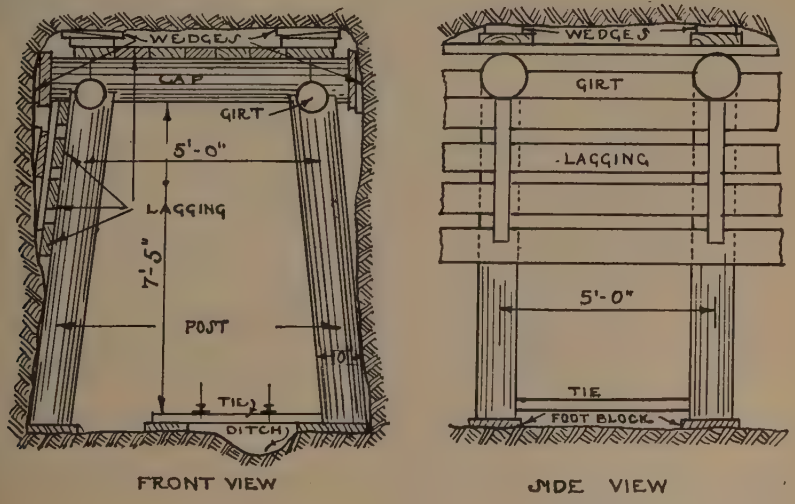


(*Courtesy Bureau of Mines.*)

FIG. 225.—One- and two-piece drift sets used in metal mining: *A*, One-piece drift set; *B*, two-piece drift set; *a*, stull; *b*, hanging-wall head block; *c*, foot-wall hitch; *d*, angle post; *e*, footboard for post; *f*, pole lagging; *g*, wedge; *h*, dap or seat for post.

a long period of service is desired, treated timbers are the most economical as well as the most satisfactory to use.

The framing of mine timbers should be done in the open air, after measurements of right lengths and necessary details have been made and recorded in the mine.



(*Courtesy Bureau of Mines.*)

FIG. 226.—Three-piece set for timbering a drift showing both front and side views.

Of the numerous methods of timbering, the one which provides a safe support for the mine will be found to be the least expensive in the end.

The simplest form of roof for a mine or tunnel is a single timber, and the next would, of course, be the two-piece set. Figure 225 illustrates these two types of roof.

The one-piece set is used where the gound is firm and only occasional loose rock in the roof needs support. The two-piece set offers a means of supporting the hanging side wall, if necessary, and provides a stronger

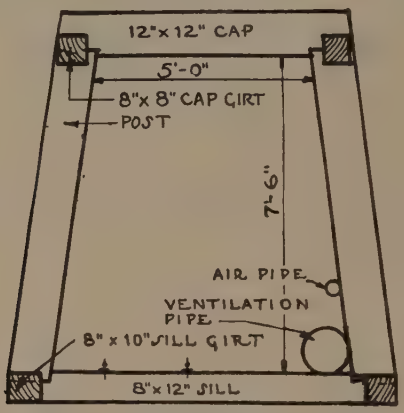
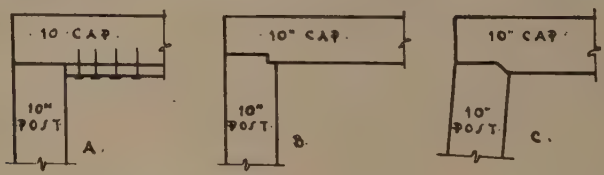


FIG. 227.—Four-piece drift timber set.

roof or back support. Lagging may be added, bearing on the inclined posts, to support loose material between the bents, as shown.

Where the ground is less stable, or "medium," additional support is gained by using a three-piece set, as shown in Fig. 226; and if the bottom is soft, a sill may be added, as seen in the four-piece set in Fig. 227.

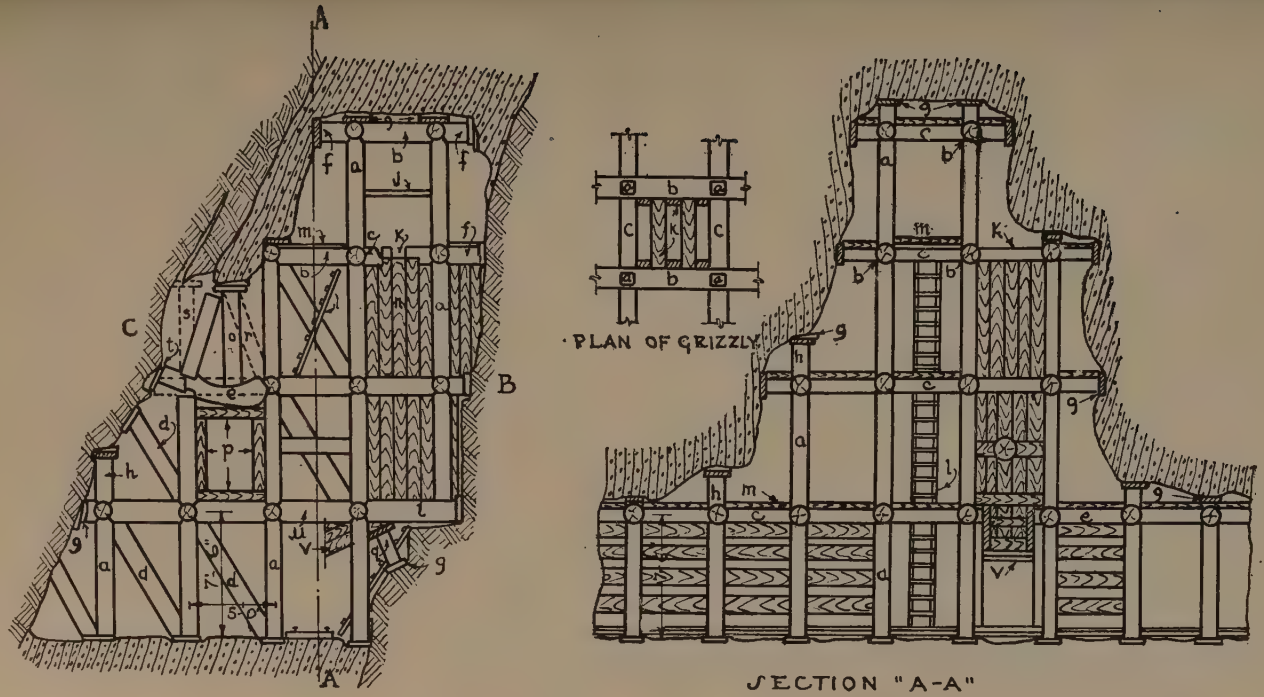


SIMPLE JOINTS USED IN DRIFT TIMBERING

A CORRECT METHOD OF JOINING CAP AND POST
B INCORRECT METHOD
C CORRECT METHOD OF JOINING CAP AND POST ON A BEVEL

FIG. 228.—Three methods of joining posts and caps in drift timbering.

In these sets, as in the more elaborate ones used for extremely heavy ground, and for timbering vertical or inclined shafts and intersections it is of prime importance to use properly made joints. The general statement that a joint is the weakest part of any timber structure finds no exception in mine timbering.



(*Courtesy Bureau of Mines.*)

FIG. 229.—Stull and post method of stope timbering, showing cross-section and lengthwise section of the stope; A-A, Cross-section of drift; B, foot wall: C, hanging wall; *a*, posts; *b*, stulls; *c*, girts; *d*, angle braces; *e*, broken cap or girt; *f*, butt caps; *g*, head blocks; *h*, short posts; *i*, cap sills; *j*, guard rail, *k*, grizzly; *l*, ladder; *m*, stope lagging; *n*, chute lagging; *o*, post, wrongly placed; *p*, doubling-up set; *q*, chute brace; *r*, angle brace; *s*, proper position for post; *t*, hanging wall left unsupported by breaking of cap; *u*, drift cap; *v*, chute.

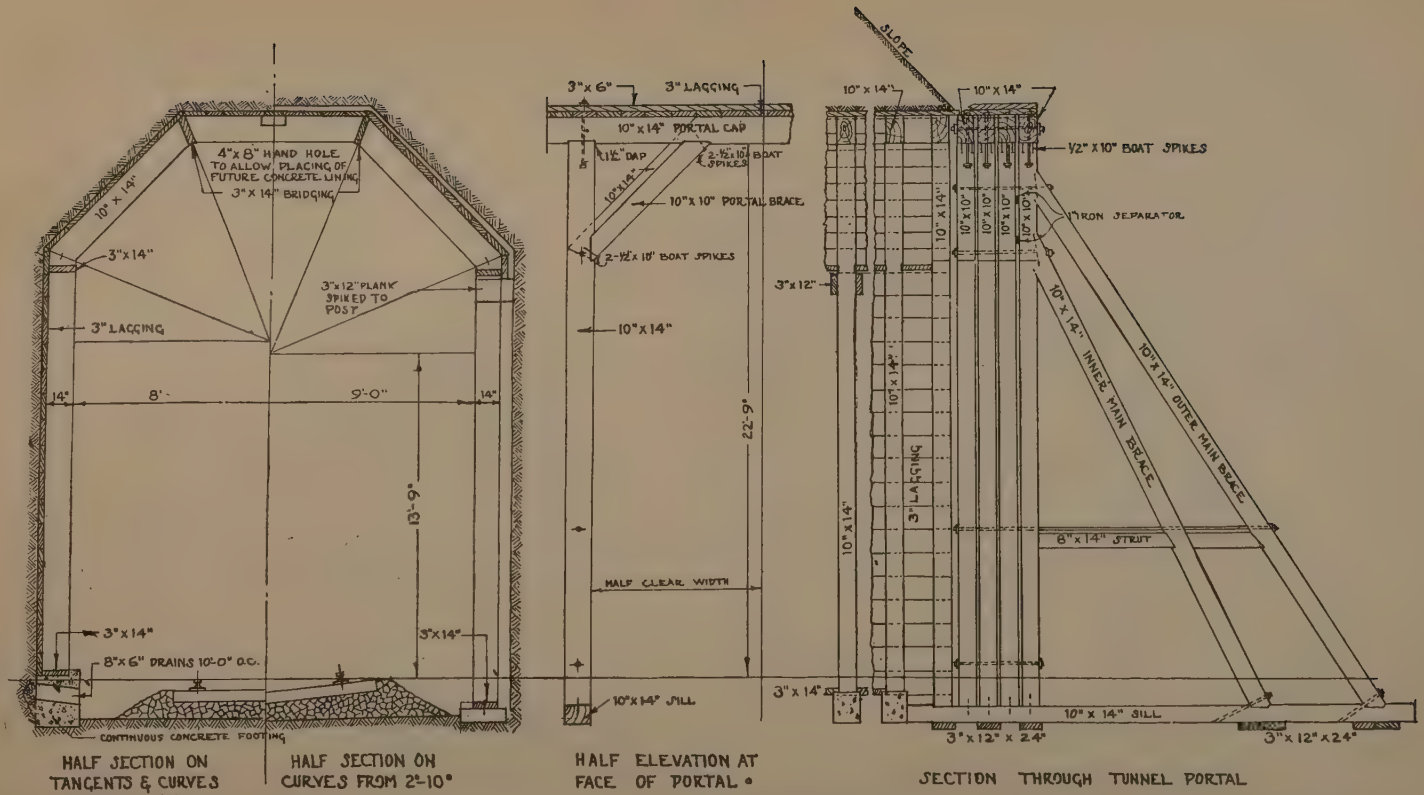


FIG. 230.—Common standard timber lining for tunnels.

Figure 228 shows three methods of framing caps to posts in drift timbering. The detail *B*, though frequently used, is not recommended. Accurate cutting of the pieces is required for this joint, and the timbers must be correctly placed; in addition to this the post is weakened.

A better method, and one suitable for either round or square timbers, is shown in detail *C*. In both cases, the posts should be battered, usually about ½ in. to each 12 in. Thus placed, they afford better protection from side pressure and allow the use of shorter caps for the same width at the bottom of the drift.

Figure 229 illustrates a common method in *stope* timbering, a name given the timbering used where ore is to be removed from an underground deposit.

In this type of timbering, the posts should be placed above each other. Note the wrongly placed post *p* in the figure and the doubling-up set used below, after the failure of the cap.

Figure 230 shows a standard type of timbering for tunnels and portals. It has been used by railroad and other companies.

FOUNDATION TIMBERING

In foundation work the temporary use of wood may involve footings, sheet piling, cribbing, bracing of excavations, and various combinations of all these.

Footings are usually simple sills or plank grillages of one or more courses, as dictated by soil or by loading.

Wooden sheet piling is often used for a temporary wall to exclude earth, and sometimes water, from areas to be excavated. If an earth bank is to be supported, a single row of planks, driven with abutting sides, will serve the purpose provided that the bracing is adequate. If watertightness is desired, however, and if considerable pressure is to be resisted, three thicknesses of plank may be nailed together so that the center plank forms a tongue and groove of from 2½ to 4 in. This type of wood sheet piling is known as *Wakefield*. If 2-in. planks are used, the tongue should be from 2½ to 3 in.; for 3-in. plank, the tongue should be 3½ to 4 in.; and for 4-in. plank, a 4-in. tongue is best. The planks should be spiked together with nails at least ½ in. longer than the combined thickness of the three pieces, to allow for clinching. Half the nails are driven from one side and half from the other side of the built-up pile and are spaced about 1 ft. apart for several feet from each end of the pile and from 3 to 4 ft. apart toward the center. The ends are beveled to facilitate driving and prevent brooming. Southern pine and Douglas fir are two of the woods most commonly used in this work. They should be dressed on all four sides.

For many years, this Wakefield sheet piling was considered one of the best types of wood sheathing. In the last few years, an improved,

patented type of interlocking sheet piling, known as the *Martincz*, after the name of its inventor, has been developed. It has been extensively and successfully used along the Mississippi River in connection with levees for flood relief, where other types have failed, and has been recom-

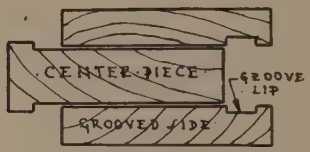


FIG. 231.—Interlocking wood sheet piling.

mended by many prominent engineers who are familiar with its performance. Figure 231 shows a section through a typical unit. The interlocking feature is obtained by fitting the "head" of the center piece into the grooves of the two outside pieces. The planks are nailed together as in Wakefield piling.

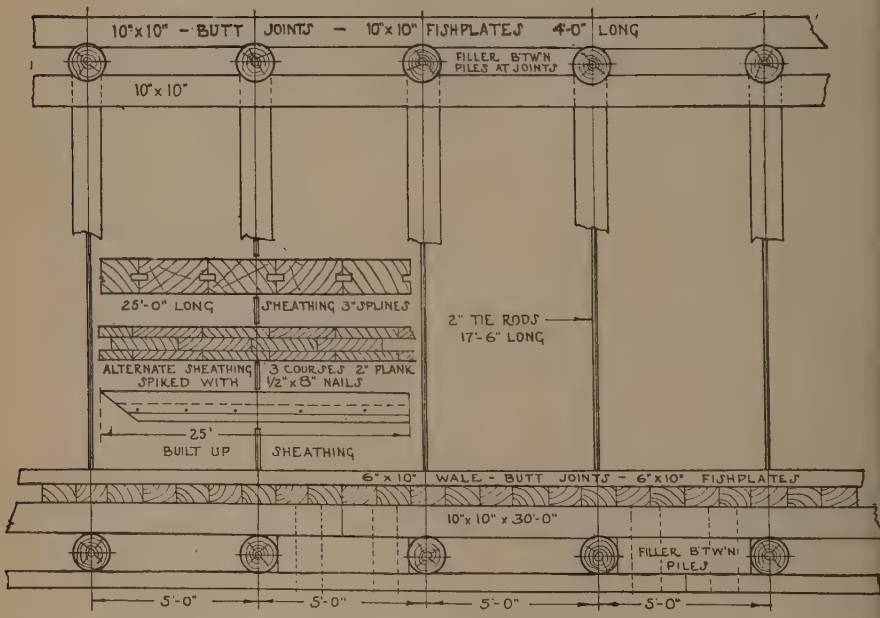


FIG. 232.—Temporary wooden bulkhead.

This piling is claimed to be the only watertight piling of any material and has been used in the base of levees to make them secure against "blow outs" and to save the base, even if the levee should be overtopped by floods.

Figure 232 shows part of a temporary bulkhead in Pouch Terminal at Carteret, New Jersey. A 4-in. splined sheathing was proposed, with a built-up sheathing, similar to Wakefield piling, as an alternate.

Timber cribbing is used in various ways to serve as a cofferdam; also, it is sometimes used as a temporary pier for a bridge. The framing does not involve any special difficulty; the members are drift bolted together, one timber being simply put on top of another; at the corners, the pieces are usually halved and bolted.

In the foundation of the Ohio Bell Telephone Company's Building at Cleveland, Ohio, excavations had to be carried down approximately 53 ft. below grade, so that an elaborate system of foundation bracing and sheathing of both steel and wood was necessary, as shown in Figs. 233*a* and *b*. The size of the braces was computed from the column formula:

$$S = 1{,}300\left(1 - \frac{l}{80d}\right)$$

The maximum stress to which a set of timbers will be subjected in foundation bracing occurs during the successive placing of the tiers of braces rather than after all the tiers are in place. For, if the excavation has been carried down far enough for three tiers to be erected, then, as the excavation deepens to the fourth-tier level, the third tier will have to to take the reaction of the wall from the second tier down to a point somewhat below the fourth-tier level, until the fourth tier has been placed.

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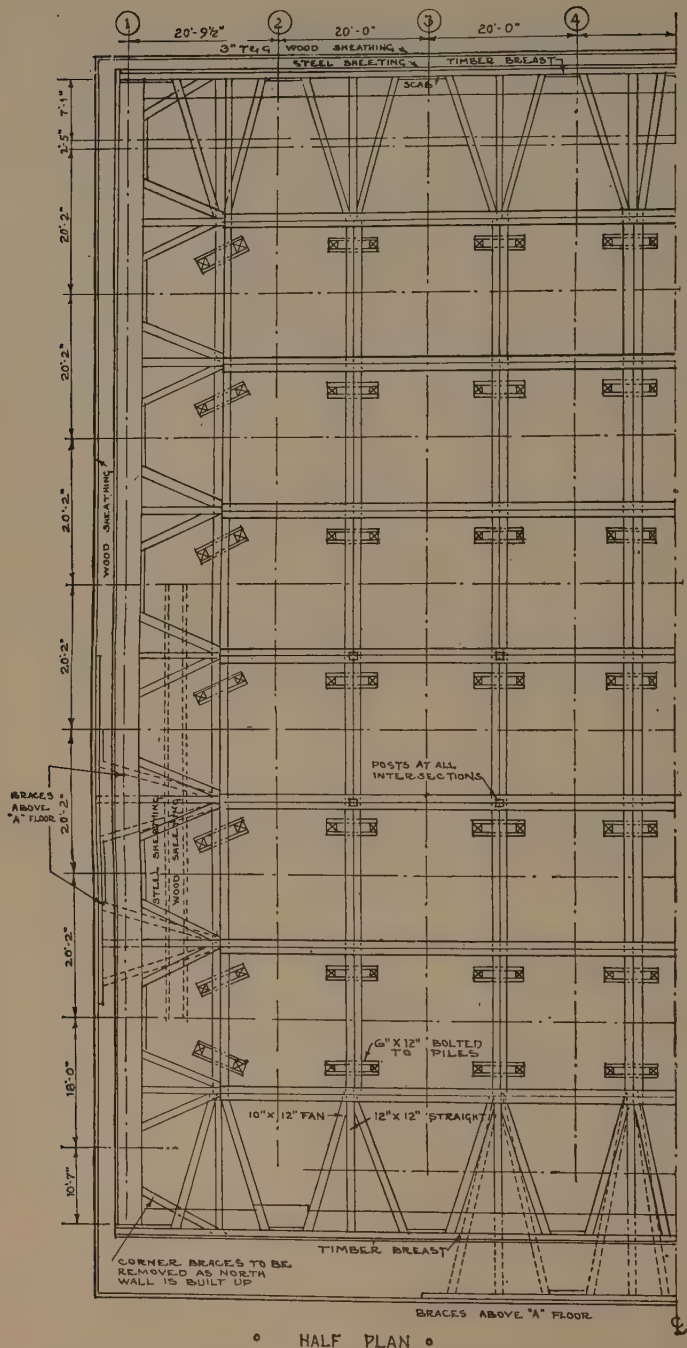

HALF PLAN

FIG. 233*a*.—Half plan of cross-lot bracing for deep excavation—Ohio Bell Telephone Company's building at Cleveland, Ohio.

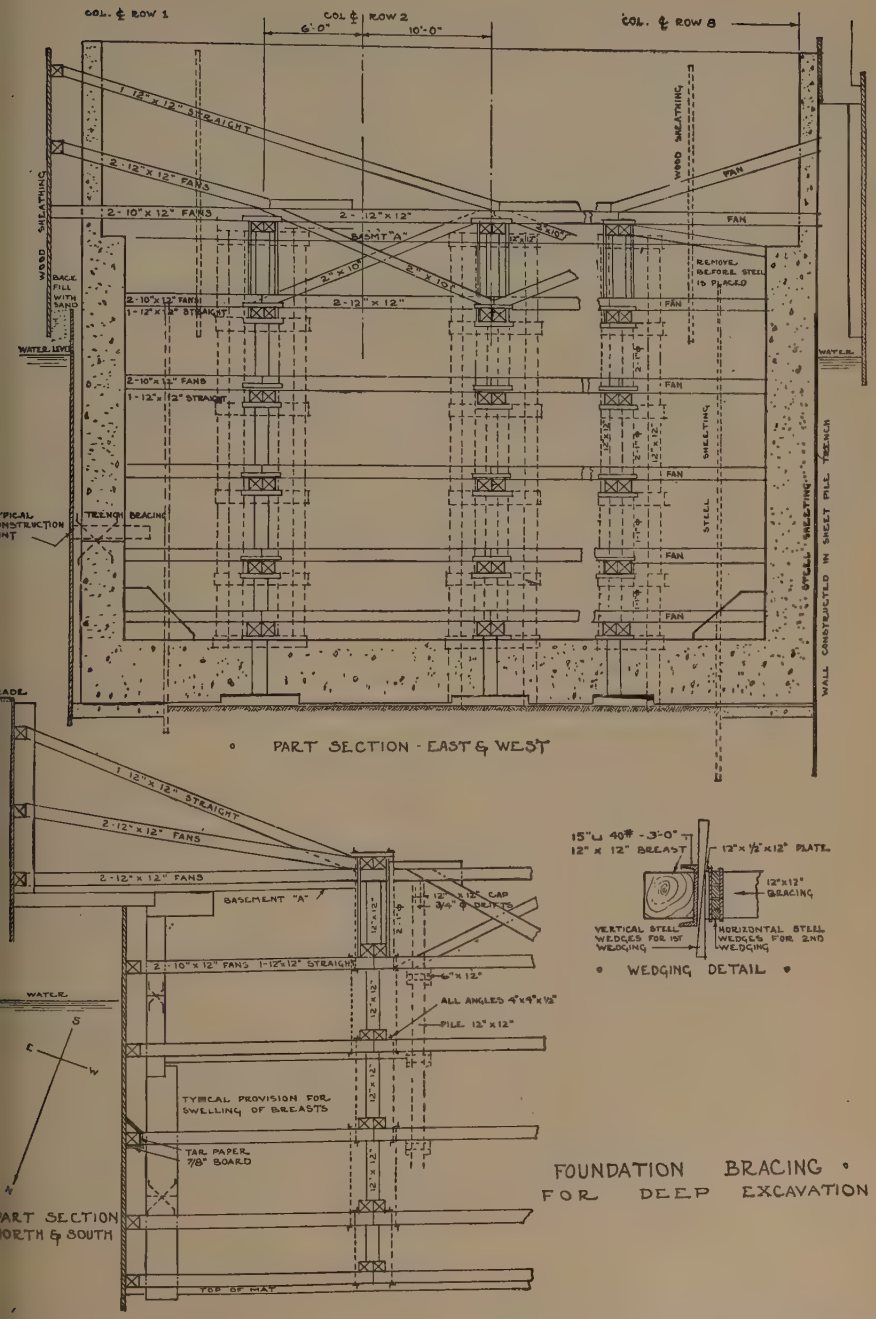

FIG. 233b.—Part section of cross-lot bracing for Ohio Bell Telephone Company's building at Cleveland, Ohio. (See Fig. 233a.)

APPENDIX

The following pages contain three groups of tables showing:

Weights of Various Softwoods Grown in the United States, Pages 599 and 600.

Grades of Yard-Lumber Products Cut From Various Species of Softwoods, Pages 601 to 605.

Range of Grades of Softwood Lumber Used for Specific Purposes, Pages 606 to 689.

WEIGHTS OF VARIOUS SOFTWOODS GROWN IN THE UNITED STATES [1]

Standard commercial name	Weight per cubic foot	
	Green	Air dry—12 per cent moisture content
Cedars:		
Alaska cedar	35	29
Eastern red cedar	37	33
Incense cedar	45	26
Northern white cedar	28	22
Port Orford cedar	36	29
Southern white cedar	26	23
Western red cedar	27	23
Cypress:		
Southern cypress	51	32
Douglas fir:		
Douglas fir (coast type)	38	34
Red fir (mountain type)	35	30
The true firs:		
Alpine fir	28	23
Balsam fir	45	26
Red fir	48	27
Noble fir	30	26
Silver fir	36	27
White fir	47	26

[1] This table shows the average weight per cubic foot of various softwoods. The green weights are for material at the moisture condition of the trees when felled. The air-dry weights are for wood at a moisture content of 12 per cent, which is approximately the condition reached without artifical heating by material sheltered from precipitation in the North Central states.

While the weights shown are based on clear material and do not exactly represent the weight of lumber and timber containing defects, they are fairly representative and offer a means of comparing the corresponding grades of the different woods.

WEIGHTS OF VARIOUS SOFTWOODS GROWN IN THE UNITED STATES.—(*Continued*)

Standard commercial name	Weight per cubic foot	
	Green	Air dry—12 per cent moisture content
Hemlocks:		
Eastern hemlock	49	28
Mountain hemlock	44	31
West Coast hemlock	42	28
Larch:		
Western larch	48	36
Pines:		
Arkansas soft pine	51–54	38
California white pine	45	28
Idaho white pine	35	27
Jack pine	50	30
Loblolly pine	54	38
Lodgepole pine	39	29
Longleaf pine	51	41
North Carolina pine	51–54	38
Northern white pine	36	25
Norway pine	42	33
Pond pine	49	38
Pondosa pine	45	28
Shortleaf pine	51	38
Slash pine	56	48
Sugar pine	51	25
Redwood:		
Redwood	54	30
Spruces:		
Eastern spruce	32–34	27–28
Engelmann spruce	39	23
Sitka spruce	32	27
Tamarack:		
Tamarack	47	37
Yew:		
Pacific yew	54	44

GRADES OF YARD-LUMBER PRODUCTS CUT FROM VARIOUS SPECIES OF SOFTWOODS

This chart shows in condensed form the American Standard Association grades produced in the various items from the woods shown in the column headings (see footnote below).

Product	Western red cedar	California redwood	Red cypress
	West Coast Lumbermen's Association	California Redwood Association	Southern Cypress Manufacturers Association
	Names of grades	Names of grades	Names of grades
Finish	B and better	Clear heart	Clear heart
		A	A
		B	B
	.....	C	C
	.....	D	D
Common boards and strips.	No. 1 common	No. 1 common	No. 1 common
Rough, dressed, D & M, and shiplap	No. 2 common	No. 2 common	No. 2 common
		No. 3 common	No. 3 common
	.....	.....	No. 4 common
Flooring, flat grain	B and better	Clear heart	
		A	A (all heart)
		B	B
	C	.....	C
	.....	.....	D
Siding bevel or drop	Clear (bevel)	Clear heart (bevel and drop)	
	A (bevel)	A (bevel and drop)	A
	B (bevel)	B (bevel and drop)	B
	C (bevel)	.....	C
	.....	.....	D
	.....	No. 1 common (drop)	
Ceiling and partition	.....	Clear heart	
	.....	A	A (all heart)
	.....	B	B
	.....	.....	C
	.....	.....	D
Moldings	.....	A and better	B and better
	.....	.....	
Dimension and heavy joists (or planks)	No. 1 common	No. 1 common	No. 1 common
	No. 2 common	No. 2 common	No. 2 common
	.....	No. 3 common	No. 3 common
	.....	.....	No. 4 common
Factory flooring, decking and heavy shiplap	No. 1 common	No. 1 common	No. 1 common
	No. 2 common	No. 2 common	No. 2 common

The grades shown in any horizontal line are not identical in quality. They are as nearly standardized as present practice in the lumber industry will permit. They are to be interpreted in the light of paragraph 1 of the American Lumber Standards as published in *Lumber*, Simplified Practice Recommendation 16, of the U. S. Department of Commerce, as follows: "To the extent to which differences in quality of timber, in conditions of manufacture, and in the uses to which the product is put, will, in practical application, permit, the basic provisions for the grading of lumber shall be uniform."

The name of the association producing the species in question is indicated in the column heading.

A combination of two grades means lumber primarily of the base grade, *i.e.*, *B and better* is principally B grade; *C and better* is principally C grade, etc.

Blank spaces in the above table mean that the wood in question is not regularly manufactured into the grade or product opposite which the blank space appears.

Shop lumber is not included under the classification of yard lumber.

GRADES OF YARD-LUMBER PRODUCTS CUT FROM VARIOUS SPECIES OF SOFTWOODS
(*Continued*)

Product	Douglas fir (coast type)	West Coast hemlock	Sitka spruce
	West Coast Lumbermen's Association Names of grades	West Coast Lumbermen's Association Names of grades	West Coast Lumbermen's Association Names of grades
Finish	B and better	B and better	B and better
	C	C	C
	D	D	.....
Common boards and strips.	No. 1 common	No. 1 common	No. 1 common
Rough, dressed, D & M, and shiplap	No. 2 common	No. 2 common	No. 2 common
	No. 3 common	No. 3 common	No. 3 common
Flooring, flat grain	B and better	B and better	B and better
	C	C	.....
	D	D	.....
Flooring, edge grain	A	A	B and better
	B	B	
	C	C	.....
	D	D	.....
Siding, bevel or drop	A (bevel)	B and better	A (bevel)
	B and better (drop)		B (bevel)
	B (bevel)		
	C (bevel and drop)	C	C (bevel)
	D (drop)	D	
Ceiling and partition	B and better	B and better	B and better
	C	C	.....
	D	D	.....
Moldings	B and better	B and better	B and better
Dimension and heavy joists (or planks)	No. 1 common	No. 1 common	No. 1 common
	No. 2 common	No. 2 common	No. 2 common
	No. 3 common	No. 3 common	No. 3 common
Factory flooring, decking and heavy shiplap	No. 1 common	No. 1 common	No. 1 common
	No. 2 common	No. 2 common	No. 2 common

The grades shown in any horizontal line are not identical in quality. They are as nearly standardized as present practice in the lumber industry will permit. They are to be interpreted in the light of paragraph 1 of the American Lumber Standards as published in *Lumber*, Simplified Practice Recommendation 16, of the U. S. Department of Commerce, as follows: "To the extent to which differences in quality of timber, in conditions of manufacture, and in the uses to which the product is put, will, in practical application, permit, the basic provisions for the grading of lumber shall be uniform."

The name of the association producing the species in question is indicated in the column heading.

A combination of two grades means lumber primarily of the base grade, *i.e.*, *B and better* is principally B grade; *C and better* is principally C grade, etc.

Blank spaces in the above table mean that the wood in question is not regularly manufactured into the grade or product opposite which the blank space appears.

Shop lumber is not included under the classification of yard lumber.

GRADES OF YARD-LUMBER PRODUCTS CUT FROM VARIOUS SPECIES OF SOFTWOODS
(*Continued*)

Product	Longleaf and shortleaf southern pine	North Carolina pine	Eastern hemlock	Tamarack
	Southern Pine Association	North Carolina Pine Association	Northern Hemlock and Hardwood Manufacturers Association	Northern Hemlock and Hardwood Manufacturers Association
	Name of grades	Name of grades	Name of grades	Name of grades
Finish	A	B and better	D and better	D and better
	B			
	C	C		
	.....	.....		
Common boards and strips. Rough, dressed, D & M, and shiplap	No. 1 common	No. 1 common boards and strips	No. 1 common	No. 1 common
	No. 2 common	No. 2 common boards and strips	No. 2 common	No. 2 common
	No. 3 common	No. 3 common boards and strips	No. 3 common	No. 3 common
	No. 4 common	.....	No. 4 common	No. 4 common
	.....	.....	No. 5 common	No. 5 common
Flooring flat grain	A	B and better	D and better	D and better
	B			
	C	.....		
	D	.....		
	No. 1 common	No. 1 common	No. 1 common	No. 1 common
	No. 2 common	No. 2 common	No. 2 common	No. 2 common
	No. 3 common sheathing	No. 3 common sheathing	No. 3 common	No. 3 common
Flooring edge grain	A	B and better	.....	.....
	B		.....	.....
	C	.....	.....	.....
	D	.....	.....	.....
	No. 1 common	No. 1 common	.....	.....
	No. 2 common	No. 2 common	.....	.....
Siding bevel or drop	A	B and better	D and better	D and better
	B			
	.....	C		
	No. 1 common	.....	No. 1 common	No. 1 common
	No. 2 common	.....	No. 2 common	No. 2 common
	No. 3 common	.....	No. 3 common	No. 3 common
Ceiling and partition	A	B and better	D and better	D and better
	B			
	.....	.....		
	.....	.....		
	No. 1 common	No. 1 common	No. 1 common	No. 1 common
	No. 2 common	No. 2 common	No. 2 common	No. 2 common
	No. 3 common	.....	No. 3 common	No. 3 common
Moldings	B and better	B and better	D and better	.....
	.....	.....		.....
	.....	.....		.....
Dimension and heavy joists (or planks)	No. 1 common	No. 1 common	No. 1 common	No. 1 common
	No. 2 common	No. 2 common	No. 2 common	No. 2 common
	No. 3 common	No. 3 common	No. 3 common	No. 3 common
	.....	.....	No. 4 common	No. 4 common
Factory flooring, decking, and heavy shiplap	No. 1 common	.....	No. 1 common	No. 1 common
	.....	No. 2 common	No. 2 common	No. 2 common

The grades shown in any horizontal line are not identical in quality. They are as nearly standardized as present practice in the lumber industry will permit. They are to be interpreted in the light of paragraph 1 of the American Lumber Standards as published in *Lumber*, Simplified Practice Recommendation 16, of the U. S. Department of Commerce, as follows: "To the extent to which differences in quality of timber, in conditions of manufacture, and in the uses to which the product is put, will, in practical application, permit, the basic provisions for the grading of lumber shall be uniform."

The name of the association producing the species in question is indicated in the column heading.

A combination of two grades means lumber primarily of the base grade, *i.e.*, *B and better* is principally B grade; *C and better* is principally C grade, etc.

grade spaces in the above table mean that the wood in question is not regularly manufactured into the grade or product opposite which the blank space appears.

Shop lumber is not included under the classification of yard lumber.

GRADES OF YARD-LUMBER PRODUCTS CUT

Product	Sugar pine	Pondosa pine	California white pine	Idaho white pine	Larch and red fir (Douglas fir intermountain type)
	California White and Sugar Pine Manufacturers Association Name of grades	Western Pine Manufacturers Association Name of grades	California White and Sugar Pine Manufacturers Association Name of grades	Western Pine Manufacturers Association Name of grades	Western Pine Manufacturers Association Name of grades
Finish	B select and better C select D select	B select and better C select D select	B select and better C select D select	B select and better C select D select	C and better D
Common boards and stripes. Rough, dressed, D & M, and shiplap	No. 1 common No. 2 common No. 3 common No. 4 common No. 5 common	No. 1 common No. 2 common No. 3 common No. 4 common No. 5 common	No. 1 common No. 2 common No. 3 common No. 4 common No. 5 common	No. 1 common No. 2 common No. 3 common No. 4 common No. 5 common	No. 1 common No. 2 common No. 3 common No 4 common No 5 common
Flooring flat grain	....	....	....	....	C and better D No. 1 common No. 2 common No. 3 common
Siding bevel or drop	B and better (bevel) C select and better (drop) C (bevel) D (bevel) D select (drop) No. 1 common (drop) No. 2 common (drop) No. 3 common (drop)	B and better C D E .... No. 3 common or better (drop)	B and better (bevel) C select and better (drop) C (bevel) D (bevel) D select (drop) No. 1 common (drop) No. 2 common (drop) No. 3 common (drop)	B and better C D E .... No. 3 common or better (drop)	C and better D .... No. 3 common or better (drop)
Ceiling and partition	C select and better D select No. 1 common No. 2 common	B select and better C select D select No. 1 common No. 2 common No. 3 common	C select and better D select No. 1 common No. 2 common No. 3 common	B select and better C select D select No. 1 common No. 2 common No. 3 common	C select and better D No. 1 common No. 2 common No. 3 common
Moldings	C and better	C and better	C and better	C and better	.....
Dimension and heavy joists (or planks)	No. 1 common No. 2 common No. 3 common	....	No. 1 common No. 2 common No. 3 common	....	No. 1 common No. 2 common No. 3 common
Factory flooring decking, and heavy shiplap	No. 1 common No. 2 common	....	No. 1 common No. 2 common	....	No. 1 common No. 2 common

The grades shown in any horizontal line are not identical in quality. They are as nearly standardized as present practice in the lumber industry will permit. They are to be interpreted in the light of paragraph 1 of the American Lumber Standards as published in *Lumber*, Simplified Practice Recommendation 16, of the U. S. Department of Commerce, as follows: "To the extent to which differences in quality of timber, in conditions of manufacture, and in the uses to which the product is put, will, in practical application, permit, the basic provisions for the grading of lumber shall be uniform."

FROM VARIOUS SPECIES OF SOFTWOODS (*Continued*)

White fir, cedar, and spruce	White fir, incense cedar, and red fir (Douglas fir intermountain type)	Northern white pine	Norway pine	Eastern spruce	Tamarack
Western Pine Manufacturers Association Name of grades	California White and Sugar Pine Manufacturers Association Name of grades	Northern Pine Manufacturers Association Name of grades	Northern Pine Manufacturers Association Name of grades	Northern Pine Manufacturers Association Name of grades	Northern Pine Manufacturers Association Name of grades
B select and better	C select and better	B select and better	B select and better	B select and better	B select and better
C select		C	C	C	C
D select	D select	D	D	D	D
No. 1 common	No. 1 common	No. 1 common	No. 1 common	No. 1 common	No. 1 common
No. 2 common	No. 2 common	No. 2 common	No. 2 common	No. 2 common	No. 2 common
No. 3 common	No. 3 common	No. 3 common	No. 3 common	No. 3 common	No. 3 common
No. 4 common	No. 4 common	No. 4 common	No. 4 common	No. 4 common	No. 4 common
No. 5 common	No. 5 common	No. 5 common	No. 5 common	No. 5 common	No. 5 common
.....	C select and better	.....	.....	.....	.....
.....		.....	.....	.....	.....
.....		.....	.....	.....	.....
.....	D select	D	D	D	D
.....	No. 1 common	No. 1 common	No. 1 common	No. 1 common	No. 1 common
.....	No. 2 common	No. 2 common	No. 2 common	No. 2 common	No. 2 common
.....	No. 3 common	No. 3 common	No. 3 common	No. 3 common	No. 3 common
B and better	B and better (bevel)	B and better (bevel) C (bevel)	B and better (bevel)	B and better (bevel)	B and better (bevel)
C	C select and better (drop)				
	C (bevel)		C (bevel)	C (bevel)	C (bevel)
D	D (bevel) D select (drop)	D (bevel)	D (bevel)	D (bevel)	D (bevel)
.....	No. 1 common (drop)	No. 1 common (drop)	No. 1 common (drop)	No. 1 common (drop)	No. 1 common (drop)
.....	No. 2 common (drop)	No. 2 common (drop)	No. 2 common (drop)	No. 2 common (drop)	No. 2 common (drop)
.....	No. 3 common (drop)	No. 3 common (drop)	No. 3 common (drop)	No. 3 common (drop)	No. 3 common (drop)
B select and better	C select and better	.....	.....	.....	.....
C select		.....	.....	.....	.....
D select	D select	.....	.....	.....	.....
No. 1 common	No. 1 common	No. 1 common	No. 1 common	No. 1 common	No. 1 common
No. 2 common	No. 2 common	No. 2 common	No. 2 common	No. 2 common	No. 2 common
No. 3 common	No. 3 common	No. 3 common	No. 3 common	No. 3 common	No. 3 common
.....	.....	C and better	C and better	.....	.....
.....	.....			.....	.....
.....	.....			.....	.....
No. 1 common	No. 1 common	No. 1 common	No. 1 common	No. 1 common	No. 1 common
No. 2 common	No. 2 common	No. 2 common	No. 2 common	No. 2 common	No. 2 common
No. 3 common	No. 3 common	No. 3 common	No. 3 common	No. 3 common	No. 3 common
No. 1 common	No. 1 common	No. 1 common	No. 1 common	No. 1 common	No. 1 common
No. 2 common	No. 2 common	No. 2 common	No. 2 common	No. 2 common	No. 2 common

The name of the association producing the species in question is indicated in the column heading.

A combination of two grades means lumber primarily of the base grade, *i.e.*, *B and better* is principally B grade; *C and better* is principally C grade, etc.

Blank spaces in the above table mean that the wood in question is not regularly manufactured into the grade or product opposite which the blank space appears.

Shop lumber is not included under the classification of yard lumber.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES

Dwelling construction	Red cypress	Redwood
	Southern Cypress Manufacturers Association	California Redwood Association
Interior uses:		
Finish and woodwork (natural finish)	ClHt-**A-B**	**ClHt**
Finish and woodwork (paint finish)	**C-D**	ClHt-**A**
Moldings (natural and paint finish)	**B&Btr**	**A&Btr**
Flooring:		
Living and dining room, hall, etc		
Bedroom		
Kitchen (not to be covered)		
Kitchen (to be covered)		
Shelving	D-**1com**	ClHt-**A**
Stepping	**C&Btr**	
Exterior uses:		
Window and door frames	**C&Btr**	ClHt-**A**
Bungalow and colonial siding	A-**B**-C-D	ClHt-**A**
Bevel siding	A-**B**-C-D	ClHt-**A**
Rustic and drop siding	A-**B**-C-D	ClHt-**A**
Porch flooring (covered)	A-**B**	ClHt(E)-**A(E)**
Porch flooring (uncovered)	A-**B**	**ClHt(E)**
Stepping	ClHt-A-**B**-C-1com	ClHt(E)
Exterior trim	**C-D**-1com	**ClHt-A**
Sheathing, etc.:		
Wall sheathing	1com-**2com**-3com	Ht1com-**2com**
Roof sheathing	1com-**2com**-3com	Ht1com-**2com**
Subflooring	1com-**2com**-3com	Ht1com-**2com**
Framing:		
Posts	**1com**	**Ht1com**-2com
Girders	**1com**	**Ht1com**-2com
Sills	**1com**-2com	**Ht1com**-2com
Joists and rafters	**1com**-2com	**Ht1com**-2com
Plates, headers, braces	1com-**2com**	Ht1com-**2com**
Studs	1com-**2com**	Ht1com-**2com**
Cross-bridging, ribbons, ties	1com-**2com**	Ht1com-**2com**

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Farm uses	Red cypress	Redwood
	Southern Cypress Manufacturers Association	California Redwood Association
Barns and other large buildings:		
Framing:		
Posts	**1com**	**Ht1com**
Girders	**1com**	**Ht1com**
Sills	**1com**-2com	**Ht1com**-2com
Joists, rafters, trusses, plates and headers, braces, collar-beams	**1com**-2com	**Ht1com**-2com
Studs	**1com**-2com	**Ht1com**-2com
Cross-bridging, ribbons	1com-**2com**	Ht1com-**2com**
Drop siding, barn boards, and battens	D-**1com**-2com	**Ht1com**-2com
Exterior trim and doors	D-**1com**-2com	**Ht1com**-2com
Sheathing, roof and wall	**2com**-3com	Ht1com-**2com**
Heavy flooring	**1com**-2com	**Ht1com**-2com
Subflooring	1com-**2com**-3com	Ht1com-**2com**
Grooved roofing	**1com**-2com	**Ht1com**-2com
Stanchions and stalls	**1com**-2com	**Ht1com**-2com
Mangers	1com-**2com**	**Ht1com**-2com
Small farm structures (separate and lean-to sheds, stock shelters, hog, poultry, and dairy houses, small granaries):		
Framing:		
Posts, girders, sills, joists, rafters	1com-**2com**	Ht1com-**2com**-3com
Studs, plates, headers, braces, collar ties, cross-bridging, ribbons	**2com**-3com	**2com**-3com
Siding, barn boards, exterior trim	1com-**2com**-3com	Ht1com-**2com**
Flooring	**1com**-2com	**Ht1com**-2com
Sheathing (covered)	2com-**3com**	**2com**-3com
Inside equipment (roosts, nests, racks, shelving)	1com-**2com**-3com	Ht1com-**2com**-3com
Corn cribbing	**1com**-2com	**C&Btr**
Gates and fencing	1com-**2com**-3com	**Ht1com**-2com
General uses related to building construction		
Scaffolding	**1com**-2com	**Ht1com**
Staging	**1com**	**Ht1com**
Concrete forms:		
Boards	1com-**2com**-3com	Ht1com-**2com**
Dimension	**2com**-3com	Ht1com-**2com**

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red cypress	Redwood
		Southern Cypress Manufacturers Association	California Redwood Association
Bridge and construction timber:			
Combination and Howe truss spans:			
Compression members	Posts and timbers	**Sel-Com	**Sel-Com
Tension	Joist and plank	**Sel-Com	**Sel-Com
Diagonals subject to reverse stress	Posts and timbers	**Sel-Com	**Sel-Com
Floor beams and stringers	Beams and stringers	**Sel-Com	**Sel-Com
Ties	Timbers	**Sel-Com	**Sel-Com
Guard timbers	Timbers	**Sel-Com	**Sel-Com
Railing	Dimension	1com	1com
Stiffeners	Dimension	1com	1com
Splices	Dimension	1com	1com
Nailing strips	Dimension	1com	1com
Grillage	Timbers	**Sel-Com	**Sel-Com
Deck plank	Dimension	1com	1com
Bridging	Boards	1com-2com	1com-2com
Pile and frame trestles:			
Sills and mud sills	Timbers	**Sel-Com	**Sel-Com
Posts	Posts	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	**Sel-Com
Sash bracing	Plank	**Sel-Com	**Sel-Com
Cross-bracing	Plank	**Sel-Com	**Sel-Com
Longitudinal bracing	Plank	**Sel-Com	**Sel-Com
Girts	Timbers	**Sel-Com	**Sel-Com
End planks	Planks	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	**Sel-Com
Ties	Timbers	**Sel-Com	**Sel-Com
Guard timbers	Timbers	**Sel-Com	**Sel-Com
Planking for ballasted deck	Plank	**Sel-Com	**Sel-Com
Railing	Dimension	1com	1com
False work:			
Sills and mud sills	Timbers	**Sel-Com	**Sel-Com
Posts	Posts	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	**Sel-Com
Truss timbers	Timbers	**Sel-Com	**Sel-Com
Centering	Dimension	1com	1com
Lagging	Dimension	1com	1com
Bracing	Plank	**Sel-Com	**Sel-Com
Wedges	Dimension	1com	1com
Scaffolding	Dimension	1com-2com	1com-2com
Concrete forms:			
Dimension lumber	Dimension	1com-2com	1com-2com
D & M planks	.....	1com-2com	1com-2com
Bracing	Boards	1com-2com	1com-2com
Tanks and supports:			
Sills	Timbers	**Sel-Com	**Sel-Com
Posts	Posts	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	**Sel-Com
Bracing	Plank	**Sel-Com	**Sel-Com
Joists	Joists	**Sel-Com	**Sel-Com
D & M flooring	Heavy flooring	C	*B
*Staves	.....	*Tank stock	*ClHt-A
Rafters	Dimension	1com-2com	1com-2com
Roof	Shiplap	1com-2com	1com-2com
Ladders, etc	.....	C-1com	C-1com
Frost-box material	Shiplap	1com-2com	1com-2com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red cypress	Redwood
		Southern Cypress Manufacturers Association	California Redwood Association
Docks and wharves:			
Timber sheet piling	Timbers	**Sel-Com	**Sel-Com
Timber in cribs	Timbers	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	**Sel-Com
Bracing	Plank	**Sel-Com	**Sel-Com
Guard timber	Timbers	**Sel-Com	**Sel-Com
Ties	Timbers	**Sel-Com	**Sel-Com
Plank decking	Plank	**Sel-Com	**Sel-Com
Mooring posts	Timbers		
Fenders and wales	Timbers	**Sel-Com	**Sel-Com
Coaling and ore stations:			
Sills and mud sills	Timbers	**Sel-Com	**Sel-Com
Posts	Posts	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	**Sel-Com
Bracing	Plank	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	**Sel-Com
Joists	Joists	**Sel-Com	**Sel-Com
Bin lining	Dimension	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com
Flooring	Boards	1com-2com	1com-2com
Chutes	Boards	1com-2com	1com-2com
Decking	Boards	1com-2com	1com-2com
Coal pockets and bins	Dimension	1com-2com	1com-2com
Roofing	Shiplap	1com-2com	1com-2com
Tunnels:			
Posts	Posts	**Sel-Com	**Sel-Com
Sills	Timbers	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	**Sel-Com
Segments	Timbers	**Sel-Com	**Sel-Com
Lagging	Dimension	1com-2com	1com-2com
Struts	Dimension	1com-2com	2com-2com
Caisson	Timbers	**Sel-Com	**Sel-Com

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

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The names of the associations publishing rules covering the various species are shown in the column headings.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red cypress	Redwood
		Southern Cypress Manufacturers Association	California Redwood Association
Station buildings, passenger, freight, platform shelters:			
Caps	Timbers	**Sel-Com	**Sel-Com
Sills	Timbers	**Sel-Com	**Sel-Com
Posts	Timbers	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	**Sel-Com
Joists	Joists	**Sel-Com	**Sel-Com
Bridging	Boards	2com-3com	2com-3com
Subflooring	Shiplap	1com-2com-3com	1com-2com
Finish Flooring (natural finish)	Flooring		
Finish Flooring (paint finish)	Flooring		
Studding and plates	Dimension	1com-2com	1com-2com
Sheathing	Shiplap	1com-2com-3com	1com-2com
Furring	Strips	1com-2com-3com	1com-2com
Siding	Siding	A-B-C-D	*ClHt-A
Ceiling (natural finish)	Ceiling	ClHt-A-B	*ClHt
Ceiling (paint finish)	Ceiling	C-D	*ClHt-A
Truss timbers	Dimension	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com
Shingles (roof)	Shingles	*Bests	*Clear V.G.
Shingles (side walls)	Shingles	*Prime	*Star A Star
Door and window frames	Finish lumber	C&Btr	*ClrHt-A
Outside finish lumber	Finish lumber	B-C-D	*ClHt-A
Inside Finish (natural)	Finish lumber	ClHt-A-B	*ClHt
Inside Finish (paint)	Finish lumber	C-D	*ClHt-A
Millwork (moldings)	Molding	B&Btr	A&Btr
Millwork (stairs)	Finish lumber	ClHt-A-B-C	ClHt-A
Partitions	Partition	A-B-C-D	*ClHt-A
Shelving	Finish lumber	B-C-D	ClHt-A-B
Engine houses and machine shops:			
Caps	Timbers	**Sel-Com	**Sel-Com
Sills	Timbers	**Sel-Com	**Sel-Com
Posts	Timbers	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	**Sel-Com
Joists	Joists	**Sel-Com	**Sel-Com
Bridging	Boards	2com-3com	2com-3com
Flooring	Dimension	.....	1com or block
Pit timbers	Timbers	**Sel-Com	**Sel-Com
Studding	Dimension	1com-2com	1com-2com
Furring	Strips	1com-2com-3com	1com-2com
Siding	Siding	B-C-D-1com	*ClHt-A-B-1com
Ceiling	Ceiling	A-B-C-D	*A-B
Truss lumber	Dimension	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com
Shingles	Shingles	*Bests	*Clear V.G.
Door and window frames	Finish lumber	C&Btr	*ClHt-A
Outside finish lumber	Finish lumber	B-C-D	*ClHt-A-B
Inside finish lumber	Finish lumber	A-B-C	*ClHt-A
Millwork	Finish lumber	A-B-C	*ClHt-A
Sleepers	Dimension	1com-2com	1com-2com
Section houses and small buildings:			
Posts	Dimension	1com-2com	1com-2com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red cypress — Southern Cypress Manufacturers Association	Redwood — California Redwood Association
Sills	Dimension	1com-**2com**	1com-**2com**
Caps	Dimension	1com-**2com**	1com-**2com**
Joists (section houses)	Dimension	**1com**	**1com**
Joists (small buildings)	Joist	**Sel-Com	**Sel-Com
Bridging	Boards	2com-**3com**	2com-**3com**
Subflooring	Shiplap	1com-**2com**-3com	1com-**2com**-3com
Finish Flooring (natural finish)	Flooring		
Finish Flooring (paint finish)	Flooring		
Studding and plates	Dimension	**1com**-2com	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com	1com-**2com**-3com
Siding	Siding	A-B-C-D	ClHt-A-B-1com
Ceiling	Ceiling	A-B-C-D	*A-B
Rafters	Dimension	**1com**-2com	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com	1com-**2com**
Shingles	Shingles	*Bests	*Clear V.G.
Door and window frames	Finish lumber	C&Btr	*ClHt-A
Outside finish lumber	Finish lumber	B-C-D	*ClHt-A
Inside finish lumber	Finish lumber	A-B-C	*ClHt-A
Millwork	Finish lumber	A-B-C	*ClHt-A
Warehouses and ice houses:			
Caps	Timbers	**Sel-Com	**Sel-Com
Sills	Timbers	**Sel-Com	**Sel-Com
Posts	Timbers	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	**Sel-Com
Joists (warehouses)	Joists	**Sel-Com	**Sel-Com
Joists (ice houses)	Dimension	**1com**	**1com**
Bridging	Boards	1com-**2com**-3com	1com-**2com**-3com
Subflooring	Boards	1com-**2com**-3com	1com-**2com**-3com
Finish flooring	Flooring		
Studding and plates	Dimension	**1com**-2com	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com	1com-**2com**-3com
Siding	Siding	A-B-C-D	*ClHtA-B-1com
Ceiling	Ceiling	A-B-C-D	*A-B
Truss timbers	Dimension	**1com**-2com	**1com**-2com
Purlins	Dimension	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com	1com-**2com**-3com
Shingles	Shingles	*Bests	*Clear V.G.
Door and window frames	Finish lumber	C&Btr	*ClHt-A
Outside finish lumber	Finish lumber	A-B-C-D	*ClHt-A-B
Inside finish lumber	Finish lumber	A-B-C	*ClHt-A
Millwork	Finish lumber	A-B-C	*ClHt-A
Sleepers	Strips	1com-**2com**-3com	1com-**2com**-3com

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red cypress	Redwood
		Southern Cypress Manufacturers Association	California Redwood Association
Miscellaneous roadway material:			
Crossing plank	Dimension	1com-2com	1com-2com
Platforms:			
Posts	Dimension	1com-2com	1com-2com
Caps	Dimension	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com
Stringers	Stringers	**Sel-Com	**Sel-Com
Joists	Joists	**Sel-Com	**Sel-Com
Bridging	Boards	2com-3com	2com-3com
Planking	Dimension	1com-2com	1com-2com
Railing	Dimension	1com-2com	1com-2com
Steps	Boards	1com-2com	1com-2com
Skids	Dimension	1com-2com	1com-2com
Stock guards:			
Posts	Dimension	1com-2com	1com-2com
Ties	Timbers	**Sel-Com	**Sel-Com
Wing fences and aprons	Boards	1com-2com	1com-2com
Slats	Boards	1com-2com	1com-2com
Fillers	Boards	1com-2com	1com-2com
Signs and posts:			
Posts	Dimension	1com-2com-peck	1com-2com
Bracing	Dimension	1com-2com-3com	1com-2com-3com
Sign boards	Finish lumber	B-C	*ClHt-A-B
Molding	Molding	*B&Btr	*A&Btr
Fencing, including snow fence:			
Posts	Dimension	1com-2com-peck	1com-2com
Bracing	Boards	1com-2com-3com	1com-2com-3com
Stringers	Dimension	1com-2com	1com-2com
Fence boards	Boards	1com-2com-3com	1com-2com
Gate materials	Boards	1com-2com	1com-2com
Stakes	Boards	1com-2com	1com-2com
Culverts and drains:			
Sills	Timbers	**Sel-Com	**Sel-Com
Bracing	Boards	1com-2com-3com	1com-2com-3com
Timbers	Timbers	**Sel-Com	**Sel-Com
Planking	Dimension	1com-2com-3com	1com-2com-3com
Grillage	Timbers	**Sel-Com	**Sel-Com
Stock pens:			
Posts	Dimension	1com-2com-peck	1com-2com
Sills	Dimension	1com-2com	1com-2com
Fencing	Dimension	1com-2com-3com	1com-2com
Studding	Dimension	1com-2com	1com-2com
Sheathing	Shiplap	1com-2com-3com	1com-2com-3com
Rafters	Dimension	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com-3com
Shingles	Shingles	*Bests-Prime	*Clear VG-Star A Star
Outside finish lumber	Finish lumber	A-B-C-D	*ClHT-A-B
Poles	Timbers	**Sel-Com	**Sel-Com
Conduits	Dimension	1com-2com	1com-2com
Bumping blocks	Timbers	**Sel-Com	**Sel-Com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red cypress	Redwood
		Southern Cypress Manufacturers Association	California Redwood Association
Railroad Cars[1]			
Battens, door	Strips	1com-2com	1com-2com
Beams, needle	Timbers		
Belt rail	Boards	1com-2com	1com-2com
Boards, card, legend, number	Finish lumber	B-C	A-B
Braces	Joists		
Carlines	Dimension	1com	1com
Decking or flooring	Heavy flooring or decking		
Open cars			
Box cars			
Stock cars			
Subflooring	.....	1com	1com
Door, header	Dimension		
Door, grain	Boards	1com	1com
Door, side	Siding	A-B-1com	ClHt-A-1com
Fascia	Finish lumber	A-B	ClHt-A
Framing, car	Joists		
Framing, box car side door	Joists	.....	**Sel-Com
Lining	Lining		
Refrigerator and box car without siding	.....	A-B	ClHt-A
Refrigerator and box car with siding	.....	1com	1com
Plank, side and end	Plank	.....	1com
Posts, corner	Joist		
Posts, door	Joist		
Roofing	Roofing		
Single board and outside double board	.....	A-B-1com	ClHt-A-1com
Double board inside	.....	1com	1com
Running boards	Finish lumber	A-B	ClHt-A
Ridge pole	Dimension	1com	1com
Siding or sheathing	Siding	A-B-1com	ClHt-A-1com
Sills	Stringers		
Stakes	Dimension		

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[1] First grade recommended is for new cars; second, for repairs.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Industrial buildings	Item	Red cypress	Redwood
		Southern cypress Manufacturers Association	California Redwood Association
Posts	Timbers	**Sel-**Com	**Sel-**Com
Caps	Timbers	**Sel-**Com	**Sel-**Com
Girders	Beams	**Sel-**Com	**Sel-**Com
Stringers	Stringers	**Sel-**Com	**Sel-**Com
Heavy joists	Joists	**Sel-**Com	**Sel-**Com
Heavy flooring	Heavy flooring	**1com**	Block
Plates	Joists	**Sel-**Com	**Sel-**Com
Truss members	Dimension	**1com-**2com	**1com-**2com
Rafters	Dimension	**1com-**2com	**1com-**2com
Roof planking	Dimension	**1com-**2com	**1com-**2com
Bridging	Boards	2com-**3com**	2com-**3com**
Sills	Timbers	**Sel-com**	**Sel-com**
Airplane hangars			
Framing:			
Sills	Dimension	**1com-**2com	**1com-**2com
Studs	Dimension	**1com-**2com	**1com-**2com
Plates	Dimension	1com-**2com**	1com-**2com**
Rafters	Dimension	**1com-**2com	**1com-**2com
Truss members	Dimension	**1com-**2com	**1com-**2com
Siding	Siding	**-B-C-D**	C1Ht-**A-B**-1C
Sheathing (wall and roof)	Shiplap	1com-**2com**-3com	1com-**2com**
Trim (exterior and interior window and door frames)	Finish lumber	A-B-C-D	C1Ht-A-B
Highway uses			
Bridges:			
Posts or columns	Posts	**Sel-Com**	**Sel-Com**
Mud sills	Timbers	**Sel-Com**	**Sel-Com**
Sills	Timbers	**Sel-Com**	**Sel-Com**
Caps	Timbers	**Sel-Com**	**Sel-Com**
Bracing	Joists	**Sel-Com**	**Sel-Com**
Truss members	Joists	**Sel-Com**	**Sel-Com**
Stringers	Stringers	**Sel-Com**	**Sel-Com**
Floor beams	Stringers	**Sel-Com**	**Sel-Com**
Bridging	Dimension	**1com-**2com	**1com-**2com
Nailing strips	Dimension	1com-**2com**	1com-**2com**
Flooring	Plank	**Sel-Com**	**Sel-Com**
Retaining pieces	Timbers	**Sel-Com**	**Sel-Com**
Wheel guards	Timbers	**Sel-Com**	**Sel-Com**
Rail posts	Posts	**1com**	**1com**
Railing	Dimension	**1com**	**1com**
Fire stops	Dimension	1com-**2com**	1com-**2com**
Stadia			
Posts	Posts	**Sel-Com**	**Sel-Com**
Stringers	Stringers	**Sel-Com**	**Sel-Com**
Braces (diagonal)	Joists	**Sel-Com**	**Sel-Com**
Seats	Finish lumber	**C1Ht-A-B**	**C1Ht-A-B**
Back rests	Dimension	**1com**	**1com**
Seat supports	Dimension	**1com**	**1com**
Planking, ramps, decks	Dimension	**1com**	**1com**
Railing	Dimension	**1com**	**1com**
Railposts	Dimension	**1com**	**1com**
Walls, front, boxes, press box	Finish lumber (pattern)	B-C-D-1com	A-B-1com

NOTE.—The grades in boldface type are suitable for use under ordinary conditions. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for use where the requirements are not exacting are shown to the right.

Association standard grades are shown except in cases where the association concerned does not publish structural grades. In such cases, the American Lumber Standards structural grades are used and are indicated by two asterisks (**).

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Dwelling construction	Eastern hemlock	Eastern spruce	Tamarack
	Northern Hemlock and Hardwood Manufacturers Association	Northern Pine Manufacturers Association	Northern Hemlock and Hardwood Manufacturers Association and Northern Pine Manufacturers Association
Interior uses:			
Finish and woodwork (natural finish)			
Finish and woodwork (paint finish)	**D&Btr**		
Moldings (natural and paint finish)	**D&Btr**		
Flooring:			
Living and dining room, hall, etc	**D&Btr**		
Bedroom	**D&Btr**		
Kitchen (not to be covered)	**D&Btr**		
Kitchen (to be covered)	**D&Btr-1com**-2com		
Shelving	D&Btr-**1com**	**1com**	
Stepping	**D&Btr**		
Exterior uses:			
Window and door frames	**D**		
Bungalow and colonial siding			
Bevel siding	**D&Btr**		
Rustic and drop siding	**D&Btr-1com**		
Porch flooring (covered)	**1com**-2com		
Porch flooring (uncovered)	**1com**-2com		
Stepping	**1com**		
Exterior trim	**D&Btr-1com**		
Sheathing, etc.:			
Wall sheathing	1com-**2com**-3com	2com-**3com**	
Roof sheathing	1com-**2com**-3com	2com-**3com**	
Subflooring	1com-**2com**-3com	**2com-3com**	
Framing:			
Posts	**1com**	**1com**	**1com**
Girders	**1com**	**1com**	**1com**
Sills	**1com**-2com	**1com**	**1com**
Joists and rafters	**1com**-2com	**1com**	**1com**
Plates, headers, braces	**1com-2com**	1com-**2com**	1com-**2com**
Studs	**1com-2com**	1com-**2com**	1com-**2com**
Cross-bridging, ribbons, ties	1com-**2com**	1com-**2com**	1com-**2com**

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Farm uses	Eastern hemlock Northern Hemlock and Hardwood Manufacturers Association	Eastern spruce Northern Pine Manufacturers Association	Tamarack Northern Hemlock and Hardwood Manufacturers Association and Northern Pine Manufacturers Association
Barns and other large buildings:			
Framing:			
Posts	**1com**	**1com**	**1com**
Girders	**1com**	**1com**	**1com**
Sills	**1com**	**1com**	**1com**
Joists, rafters, trusses, plates and headers, braces, collar beams	**1com**-2com	**1com**	**1com**
Studs	**1com**-2com	**1com**-2com	**1com**-2com
Cross-bridging, ribbons	1com-**2com**	1com-**2com**	1com-**2com**
Drop siding, barn boards, and battens	**1com**-2com	**C-1com**-2com	
Exterior trim and doors	**1com**-2com		
Sheathing, roof and wall	1com-**2com**-3com	**2com**-3com	
Heavy flooring	**1com**-2com	.....	**1com**
Subflooring	1com-**2com**-3com	**2com**-3com	
Grooved roofing	**1com**-2com		
Stanchions and stalls	**1com**-2com	**1com**	
Mangers	1com-**2com**	**1com**-2com	
Small Farm Structures (separate and lean-to sheds, stock shelters, hog, poultry, and dairy houses, small granaries)			
Framing:			
Posts, girders, sills, joists, rafters	1com-**2com**	**1com**-2com	**1com**-2com
Studs, plates, headers, braces, collar ties, cross-bridging, ribbons	1com-**2com**	**1com**-2com	**1com**-2com
Siding, barn boards, exterior trim	1com-**2com**-3com	1com-**2com**-3com	
Flooring	**1com**-2com		
Sheathing (covered)	1com-**2com**-3com	**2com**-3com-4com	
Inside equipment (roosts, nests, racks, shelving)	1com-**2com**-3com	1com-**2com**-3com	
Corn cribbing	**1com**-2com	**1com**-2com	
Gates and fencing	**1com**-2com	1com-**2com**-3com	
General uses related to building construction			
Scaffolding	**1com**-2com	**1com**	**1com**
Staging	**1com**	**1com**	**1com**
Concrete forms:			
Boards	**1com**-2com	**2com**-3com	
Dimension	**1com**-2com	**1com**-2com	**1com**-2com

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Eastern hemlock	Eastern spruce	Tamarack
		Northern Hemlock and Hardwood Manufacturers Association	Northern Pine Manufacturers Association	Northern Hemlock and Hardwood Manufacturers Association and Northern Pine Manufacturers Association
Bridge and construction timber:				
Combination and Howe truss spans:				
Compression members	Posts and timbers	**Sel-Com		
Tension	Joist and plank	**Sel-Com		
Diagonals subject to reverse stress	Posts and timbers	**Sel-Com		
Floor beams and stringers	Beams and stringers	**Sel-Com		
Ties	Timbers	**Sel-Com		
Guard timbers	Timbers	**Sel-Com		
Railing	Dimension	1com	1com	1com
Stiffeners	Dimension	1com	1com	1com
Splices	Dimension	1com	1com	1com
Nailing strips	Dimension	1com	1com	1com
Grillage	Timbers	**Sel-com		
Deck plank	Dimension	1com	1com	1com
Bridging	Boards	1com-2com	1com-2com-3com	1com-2com
Pile and frame trestles:				
Sills and mud sills	Timbers	**Sel-Com		
Posts	Posts	**Sel-Com		
Caps	Timbers	**Sel-Com		
Sash bracing	Plank	**Sel-Com		
Cross-bracing	Plank	**Sel-Com		
Longitudinal bracing	Plank	**Sel-Com		
Girts	Timbers	**Sel-Com		
End planks	Planks	**Sel-Com		
Stringers	Stringers	**Sel-Com		
Ties	Timbers	**Sel-Com		
Guard timbers	Timbers	**Sel-Com		
Planking for ballasted deck	Plank	**Sel-Com		
Railing	Dimension	1com		1com
Falsework:				
Sills and mud sills	Timbers	**Sel-Com		
Posts	Posts	**Sel-Com		
Caps	Timbers	**Sel-Com		
Stringers	Stringers	**Sel-Com		
Truss timbers	Timbers	**Sel-Com		
Centering	Dimension	1com	1com	1com
Lagging	Dimension	1com	1com	1com
Bracing	Plank	**Sel-Com		
Wedges	Dimension	1com	1com	1com
Scaffolding	Dimension	1com-2com	1com-2com	1com-2com
Concrete forms:				
Dimension lumber	Dimension	1com-2com	1com-2com	1com-2com
D & M planks	.....	1com-2com	1com-1com	1com-2com
Bracing	Boards	1com-2com	1com-2com	1com-2com
Tanks and supports:				
Sills	Timbers	**Sel-Com		
Posts	Posts	**Sel-Com		
Caps	Timbers	**Sel-Com		
Bracing	Plank	**Sel-Com		
Joists	Joist	**Sel-Com		
D & M flooring	Heavy flooring	C		C
*Staves	.....	Tank stock		Tank-stock
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof	Shiplap	1com-2com	1com-2com	
Ladders, etc	.....	D&Btr-1com	C-1com	C-1com
Frost box material	Shiplap	1com-2com	1com-2com	
Docks and wharves:				
Timber sheet piling	Timbers	**Sel-Com		
Timber in cribs	Timbers	**Sel-Com		
Caps	Timbers	**Sel-Com		
Stringers	Stringers	**Sel-Com		
Bracing	Plank	**Sel-Com		
Guard timbers	Timbers	**Sel-Com		
Ties	Timbers	**Sel-Com		
Plank decking	Plank	**Sel-Com		

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Eastern hemlock	Eastern spruce	Tamarack
		Northern Hemlock and Hardwood Manufacturers Association	Northern Pine Manufacturers Association	Northern Hemlock and Hardwood Manufacturers Association and Northern Pine Manufacturers Association
Docks and wharves, continued				
Mooring posts	Timbers			
Fenders and wales	Timbers	**Sel-Com		
Coaling and ore stations:				
Sills and mud sills	Timbers	**Sel-Com		
Posts	Posts	**Sel-Com		
Caps	Timbers	**Sel-Com		
Bracing	Plank	**Sel-Com		
Stringers	Stringers	**Sel-Com		
Joists	Joists	**Sel-Com		
Bin lining	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Flooring	Board	**1com**-2com	**1com**-2com	**1com**-2com
Chutes	Boards	**1com**-2com	**1com**-2com	**1com**-2com
Decking	Boards	**1com**-2com	**1com**-2com	**1com**-2com
Coal pockets and bins	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roofing	Shiplap	1com-**2com**	1com-**2com**	
Tunnels:				
Posts	Posts	**Sel-Com		
Sills	Timbers	**Sel-Com		
Caps	Timbers	**Sel-Com		
Segments	Timbers	**Sel-Com		
Lagging	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Struts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Caisson	Timbers	**Sel-Com		

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the left, and alternate grades of lower quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the Associations publishing rules covering the various species are shown in the column headings.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Eastern hemlock — Northern Hemlock and Hardwood Manufacturers Association	Eastern spruce — Northern Pine Manufacturers Association	Tamarack — Northern Hemlock and Hardwood Manufacturers Association and Northern Pine Manufacturers Association
Station buildings, passenger, freight, platform shelters:				
Caps	Timbers	**Sel-Com		
Sills	Timbers	**Sel-Com		
Posts	Timbers	**Sel-Com		
Stringers	Stringers	**Sel-Com		
Joists	Joists	**Sel-Com		
Bridging	Boards	2com-3com	2com-3c	
Subflooring	Shiplap	1com-2com	1com-2com	
Finish flooring (natural finish)	Flooring			
Finish flooring (paint finish)	Flooring	*D&Btr		
Studding and plates	Dimension	1com-2com	1com-2com	1com-2com
Sheathing	Shiplap	1com-2com-3com	1com-2com-3com	
Furring	Strips	1com-2com-3com	1com-2com-3com	
Siding	Siding	*D&Btr-1com		
Ceiling (natural finish)	Ceiling			
Ceiling (paint finish)	Ceiling	*D&Btr		
Truss timbers	Dimension	1com-2com	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com-3com	
Shingles (roof)	Shingles	Northern white cedar, extra A		
Shingles (side walls)	Shingles	Northern white cedar, standard A		
Door and window frames	Finish lumber	*D&Btr		
Outside finish lumber	Finish lumber	*D&Btr-1com		
Inside finish (natural finish)	Finish lumber			
Inside finish (paint finish)	Finish lumber	*D&Btr		
Millwork (moldings)	Molding	*D&Btr		
Millwork (stairs)	Finish lumber	*D&Btr		
Partitions	Partition	*D&Btr		
Shelving	Finish lumber	*D&Btr		
Engine houses and machine shops:				
Caps	Timbers	**Sel-Com		
Sills	Timbers	**Sel-Com		
Posts	Timbers	**Sel-Com		
Stringers	Stringers	**Sel-Com		
Joists	Joists	**Sel-Com		
Bridging	Boards	2com-3com	2com-3com	
Flooring	Dimension	1com	.....	1com
Pit timbers	Timbers	**Sel-Com		
Studding	Dimension	1com-2com	1com-2com	1com-2com
Furring	Strips	1com-2com-3com	1com-2com-3com	
Siding	Siding	D&Btr-1com		
Ceiling	Ceiling	D&Btr-1com		
Truss lumber	Dimension	1com-2com	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com-3com	
Shingles	Shingles	Northern white cedar, extra A		
Door and window frames	Finish lumber	*D&Btr		
Outside finish lumber	Finish lumber	*D&Btr-1com		
Inside finish lumber	Finish lumber	*D&Btr		
Millwork	Finish lumber	*D&Btr		
Sleepers	Dimension	1com-2com	1com-2com	1com-2com
Section houses and small buildings:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com	1com-2com
Caps	Dimension	1com-2com	1com-2com	1com-2com
Joists (section houses)	Dimension	1com	1com	1com
Joists (small buildings)	Joist	**Sel-Com		
Bridging	Boards	2com-3com	2com-3com	2com-3com
Subflooring	Shiplap	1com-2com-3com	1com-2com-3com	
Finish flooring (natural finish)	Flooring			
Finish flooring (paint finish)	Flooring			
Studding and plates	Dimension	1com-2com	1com-2com	1com-2com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Eastern hemlock	Eastern spruce	Tamarack
		Northern Hemlock and Hardwood Manufacturers Association	Northern Pine Manufacturers Association	Northern Hemlock and Hardwood Manufacturers Association and Northern Pine Manufacturers Association
Section houses and small buildings, continued				
Sheathing	Shiplap	1com-**2com**-3com	1com-**2com**-3com	
Furring	Strips	1com-**2com**-3com	1com-**2com**-3com	
Siding	Siding	***D&Btr-1com**		
Ceiling	Ceiling	***D&Btr-1com**		
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com	1com-**2com**-3com	
Shingles	Shingles	Northern white cedar, **extra A**		
Door and window frames	Finish lumber	***D&Btr**		
Outside finish lumber	Finish lumber	***D&Btr-1com**		
Inside finish lumber	Finish lumber	***D&Btr**		
Millwork	Finish lumber	***D&Btr**		
Warehouses and Ice houses:				
Caps	Timbers	****Sel-Com**		
Sills	Timbers	****Sel-Com**		
Posts	Timbers	****Sel-Com**		
Stringers	Stringers	****Sel-Com**		
Joists (warehouses)	Joists	****Sel-Com**		
Joists (ice houses)	Dimension	**1com**	**1com**	**1com**
Bridging	Boards	1com-**2com**-3com	1com-**2com**-3com	
Subflooring	Boards	1com-**2com**-3com	1com-**2com**-3com	
Finish flooring	Flooring			
Studding and plates	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com	1com-**2com**-3com	
Furring	Strips	1com-**2com**-3com	1com-**2com**-3com	
Siding	Siding	**D&Btr-1com**		
Ceiling	Ceiling	**D&Btr-1com**		
Truss timbers	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Purlins	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Rafters	**1com**-2com	**1com**-2com	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com	1com-**2com**-3com	
Shingles	Shingles	Northern white cedar, **extra A**		
Door and window frames	Finish lumber	***D&Btr-1com**		
Outside finish lumber	Finish lumber	***D&Btr-1com**		
Inside finish lumber	Finish lumber	***D&Btr-1com**		
Millwork	Finish lumber	***D&Btr-1com**		
Sleepers	Strips	1com-**2com**-3com	1com-**2com**-3com	

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the left, and alternate grades of lower quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the associations publishing rules covering the various species are shown in the column headings.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Eastern hemlock	Eastern spruce	Tamarack
		Northern Hemlock and Hardwood Manufacturers Association	Northern Pine Manufacturers Association	Northern Hemlock and Hardwood Manufacturers Association and Northern Pine Manufacturers Association
Miscellaneous roadway material				
Crossing plank	Dimension	1com-2com	.....	1com-2com
Platforms:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Caps	Dimension	1com-2com	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com	1com-2com
Stringers	Stringers	**Sel-Com		
Joists	Joists	**Sel-Com		
Bridging	Boards	2com-3com	2com-3com	
Planking	Dimension	1com-2com	.....	1com-2com
Railing	Dimension	1com-2com	1com-2com	1com-2com
Steps	Boards	1com-2com		
Skids	Dimension	1com-2com	1com-2com	1com-2com
Stock guards:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Ties	Timbers	**Sel-Com		
Wing fences and aprons	Boards	1com-2com	1com-2com	
Slats	Boards	1com-2com	1com-2com	
Fillers	Boards	1com-2com	1com-2com	
Signs and posts:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Bracing	Dimension	1com-2com-3com	1com-2com	1com-2com-3com
Sign boards	Finish lumber	D&Btr		
Molding	Molding	*D&Btr		
Fencing, including snow fence:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Bracing	Boards	1com-2com-3com	1com-2com	
Stringers	Dimension	1com-2com	1com	1com-2com
Fence boards	Boards	1com-2com	1com-2com	1com-2com
Gate materials	Boards	1com-2com	1com-2com	1com-2com
Stakes	Boards	1com-2com	1com-2com	1com-2com
Culverts and drains:				
Sills	Timbers	**Sel-Com		
Bracing	Boards	1com-2com-3com	1com-2com-3com	
Timbers	Timbers	**Sel-Com		
Planking	Dimension	1com-2com-3com	1com-2com	1com-2com-3com
Grillage	Timbers	**Sel-Com		
Stock pens:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com	1com-2com
Fencing	Dimension	1com-2com	1com-2com	1com-2com
Studding	Dimension	1com-2com	1com-2com	1com-2com
Sheathing	Shiplap	1com-2com-3com	1com-2com-3com	
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com-1com-3com	1com-2com-3com	
Shingles	Shingles	Northern white cedar—Extra A—Standard A		
Outside finish lumber	Finish lumber	*D&Btr		
Poles	Timbers	**Sel-Com		

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Eastern hemlock	Eastern spruce	Tamarack
		Northern Hemlock and Hardwood Manufacturers Association	Northern Pine Manufacturers Association	Northern Hemlock and Hardwood Manufacturers Association and Northern Pine Manufacturers Association
Conduits	Dimension	**1com-2com**	**1com-2com**	**1com-2com**
Bumping blocks	Timbers	**Sel-Com		
Railroad cars[1]				
Battens, door	Strips	**1com-2com**	**1com-2com**	
Beams, needle	Timbers			
Belt rail	Boards			
Boards, card, legend, number	Finish lumber			
Braces	Joists			
Car lines	Dimension	**1com**		
Decking or flooring	Heavy flooring or decking			
Open cars				
Box cars				
Stock cars				
Subflooring	.....	**1com**		
Door header	Dimension			
Door, grain	Boards	**1com**	**1com**	
Door, side	Siding	**D&Btr-1com**		
Fascia	Finish lumber	**D&Btr**		
Framing, car	Joists			
Framing, box car side door	Joists	**Sel-com		
Lining	Lining			
Refrigerator and box car without siding	.....	**D&Btr**		
Refrigerator and box car with siding	.....	**1com**		
Plank, side and end	Plank	**1com**	.....	**1com**
Posts, corner	Joist			
Posts, door	Joist			
Roofing	Roofing			
Single board and outside double board				
Double board inside	.....	**1com**	**1com**	
Running boards	Finish lumber			
Ridge pole	Dimension			
Siding or sheathing	Siding	**D&Btr**		
Sills	Stringers			
Stakes	Dimension	**1com**	.....	**1com**

[1] First grade recommended is for new cars; second, for repairs.

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the left, and alternate grades of lower quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the associations publishing rules covering the various species are shown in the column headings.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Industrial buildings	Item	Eastern hemlock — Northern Hemlock and Hardwood Manufacturers Association	Eastern spruce — Northern Pine Manufacturers Association	Tamarack — Northern Hemlock and Hardwood Manufacturers Association and Northern Pine Manufacturers Association
Posts	Timbers	**Sel-Com	. . . .	
Caps	Timbers	**Sel-Com	. . . .	
Girders	Beams	**Sel-Com	. . . .	
Stringers	Stringers	**Sel-Com	. . . .	
Heavy joists	Joists	**Sel-Com	. . . .	
Heavy flooring	Heavy flooring	**1com**	. . . .	**1com**
Plates	Joists	**Sel-Com	. . . .	
Truss members	Dimension	**1com**-2com	**1com**-2com	**1cm**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roof planking	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Bridging	Boards	2com-**3com**	2com-**3com**	2com-**3com**
Sills	Timbers	**Sel-Com	. . . .	
Airplane hangars				
Framing:				
Sills	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Studs	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Plates	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Truss members	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Siding	Siding	**D&Btr**-1com		
Sheathing, wall and roof	Shiplap	1com-**2com**-3com	1com-**2com**-3com	
Trim, exterior and interior, window and door frames	Finish lumber	**D&Btr**-1com		
Highway uses				
Bridges:				
Posts or columns	Posts	**Sel-Com	. . . .	
Mud sills	Timbers	**Sel-Com	. . . .	
Sills	Timbers	**Sel-Com	. . . .	
Caps	Timbers	**Sel-Com	. . . .	
Bracing	Joists	**Sel-Com	. . . .	
Truss members	Joists	**Sel-Com	. . . .	
Stringers	Stringers	**Sel-Com	. . . .	
Floor beams	Stringers	**Sel-Com	. . . .	
Bridging	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Nailing strips	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Flooring	Plank	**Sel-Com	. . . .	
Retaining pieces	Timbers	**Sel-Com	. . . .	
Wheel guards	Timbers	**Sel-Com	. . . .	
Rail posts	Posts	**1com**	**1com**	**1com**
Railing	Dimension	**1com**	**1com**	**1com**
Fire stops	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Stadia				
Posts	Posts	**Sel-Com	. . . .	
Stringers	Stringers	**Sel-Com	. . . .	
Braces (diagonal)	Joists	**Sel-Com	. . . .	
Seats	Finish lumber			
Back rests	Dimension	**1com**	. . . .	**1com**
Seat supports	Dimension	**1com**	. . . .	**1com**
Planking, ramps, decks	Dimension	**1com**	. . . .	**1com**
Railing	Dimension	**1com**	. . . .	**1com**
Rail posts	Dimension	**1com**	. . . .	**1com**
Walls, front, boxes, press box	Finish lumber (pattern)	**D&Btr**-1com		

NOTE.—The grades "in bold face type," are suitable for the use under ordinary conditions. Alternate grades for unusually high quality of construction are shown to the left and alternate grades for use where the requirements are not exacting are shown to the right.

Association standard grades are shown except in cases where the association concerned does not publish structural grades. In such cases, the American Lumber Standards structural grades are used and are indicated by two asterisks (**).

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Dwelling construction	Red fir	White fir	Western larch
	Western Pine Manufacturers Association	Western Pine Manufacturers Association and California White and Sugar Pine Manufacturers Association	Western Pine Manufacturers Association
	Douglas fir		
	California White and Sugar Pine Manufacturers Association		
Interior uses:			
Finish and woodwork (natural finish)	**C&Btr**	.....	**C&Btr**
Finish and woodwork (paint finish)	**C&Btr**	**C&Btr**	**C&Btr**
Moldings (natural and paint finish)			
Flooring:			
Living and dining room, hall, etc	**C&Btr(E)**	.....	**C&Btr(E)**
Bedroom	**C&Btr-1com**	.....	**C&Btr-1com**
Kitchen (not to be covered)	**C&Btr(E)**	.....	**C&Btr(E)**
Kitchen (to be covered)	**C&Btr-1com**	.....	**C&Btr-1com**
Shelving	**D-1com**	**D-1com**	**D-1com**
Stepping	**C&Btr(E)**	.....	C&Btr(E)
Exterior uses:			
Window and door frames	**C&Btr**	**C&Btr**	**C&Btr**
Bungalow and colonial siding			
Bevel siding	**C&Btr-D**	**C&Btr-D**	**C&Btr-D**
Rustic and drop siding	**C&Btr-D-1com**	**C&Btr-D-1com**	**C&Btr-D-1com**
Porch flooring (covered)	**C&Btr**	.....	**C&Btr**
Porch flooring (uncovered)	**C&Btr(E)**	.....	**C&Btr(E)**
Stepping	**C&Btr(E)**	.....	**C&Btr(E)**
Exterior trim	**C&Btr-D**	**C&Btr-D**	**C&Btr-D**
Sheathing, etc.:			
Wall sheathing	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Roof sheathing	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Subflooring	1com-**2com**	**1com-2com**	1com-**2com**
Framing:			
Posts	**1com**	.....	**1com**
Girders	**1com**	**1com**	**1com**
Sills	**1com**	.....	**1com**
Joists and rafters	**1com**-2com	**1com**-2com	**1com**-2com
Plates, headers, braces	1com-**2com**	**1com-2com**	1com-**2com**
Studs	1com-**2com**	**1com-2com**	1com-**2com**
Cross-bridging, ribbons, ties	1com-**2com**	1com-**2com**	1com-**2com**

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Farm uses	Red fir Western Pine Manufacturers Association Douglas fir California White and Sugar Pine Manufacturers Association	White fir Western Pine Manufacturers Association and California White and Sugar Pine Manufacturers Association	Western larch Western Pine Manufacturers Association
Barns and other large buildings:			
Framing:			
Posts	**1com**	.....	**1com**
Girders	**1com**	**1com**	**1com**
Sills	**1com**	.....	**1com**
Joists, rafters, trusses, plates and headers, braces, collar beams	**1com**-2com	**1com**-2com	**1com**-2com
Studs	**1com**-2com	**1com**-2com	**1com**-2com
Cross-bridging, ribbons	1com-**2com**	1com-**2com**	1com-**2com**
Drop siding, barn boards, and battens	D-**1com**-2com	D-**1com**-2com	D-**1com**-2com
Exterior trim and doors	D-**1com**-2com	D-**1com**-2com	D-**1com**-2com
Sheathing, roof and wall	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Heavy flooring	**1com**	.....	**1com**
Subflooring	1com-**2com**	1com-**2com**	1com-**2com**
Grooved roofing	**1com**-2com	**1com**-2com	**1com**-2com
Stanchions and stalls	**1com**-2com	.....	**1com**-2com
Mangers	**1com**-2com	**1com**-2com	**1com**-2com
Small farm structures (separate and lean-to sheds, stock shelters, hog, poultry, and dairy houses, small granaries)			
Framing:			
Posts, girders, sills, joists, rafters	1com-**2com**	1com-**2com**	1com-**2com**
Studs, plates, headers, braces, collar ties, cross-bridging, ribbons	1com-**2com**	1com-**2com**	1com-**2com**
Siding, barn boards, exterior trim	**1com**-2com	**1com**-2com	**1com**-2com
Flooring	D-**1com**-2com	.....	D-**1com**-2com
Sheathing (covered)	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Inside equipment (roosts, nests, racks, shelving)	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Corn cribbing	**1com**-2com	**1com**	**1com**-2com
Gates and fencing	**1com**-2com	**1com**-2com	**1com**-2com
General uses related to building construction			
Scaffolding	**1com**-2com	**1com**	**1com**-2com
Staging	**1com**	**1com**	**1com**
Concrete forms:			
Boards	1com-**2com**-3com	**1com**-2com	1com-**2com**-3com
Dimension	**1com**-2com	**1com**-2com	**1com**-2com

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red fir Western Pine Manufacturers Association Douglas fir California White and Sugar Pine Manufacturers Association	White fir Western Pine Manufacturers Association and California White and Sugar Pine Manufacturers Association	Western larch Western Pine Manufacturers Association
Bridge and construction timber:				
Combination and Howe truss spans:				
Compression members	Posts and timbers	**Sel-Com	.....	**Sel-Com
Tension	Joist and plank	**Sel-Com	.....	**Sel-Com
Diagonals subject to reverse stress	Posts and timbers	**Sel-Com	.....	**Sel-Com
Floor beams and stringers	Beams and stringers	**Sel-Com	.....	**Sel-Com
Ties	Timbers	**Sel-Com	.....	**Sel-Com
Guard timbers	Timbers	**Sel-Com	.....	**Sel-Com
Railing	Dimension	1com	1com	1com
Stiffeners	Dimension	1com	1com	1com
Splices	Dimension	1com	1com	1com
Nailing strips	Dimension	1com	1com	1com
Grillage	Timbers	**Sel-Com	.....	**Sel-Com
Deck plank	Dimension	1com	.....	1com
Bridging	Boards	1com-2com	1com-2com	1com-2com
Pile and frame trestles:				
Sills and mud sills	Timbers	**Sel-Com	.....	**Sel-Com
Posts	Posts	**Sel-Com	.....	**Sel-Com
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Sash bracing	Plank	**Sel-Com	.....	**Sel-Com
Cross bracing	Plank	**Sel-Com	.....	**Sel-Com
Longitudinal bracing	Plank	**Sel-Com	.....	**Sel-Com
Girts	Timbers	**Sel-Com	.....	**Sel-Com
End planks	Planks	**Sel-Com	.....	**Sel-Com
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Ties	Timbers	**Sel-Com	.....	**Sel-Com
Guard timbers	Timbers	**Sel-Com	.....	**Sel-Com
Planking for ballasted deck	Plank	**Sel-Com	.....	**Sel-Com
Railing	Dimension	1com	1com	1com
Falsework:				
Sills and mud sills	Timbers	**Sel-Com	.....	**Sel-Com
Posts	Posts	**Sel-Com	.....	**Sel-Com
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Truss timbers	Timbers	**Sel-Com	.....	**Sel-Com
Centering	Dimension	1com	1com	1com
Lagging	Dimension	1com	1com	1com
Bracing	Plank	**Sel-Com	.....	**Sel-Com
Wedges	Dimension	1com	1com	1com
Scaffolding	Dimension	1com-2com	1com-2com	1com-2com
Concrete forms:				
Dimension lumber	Dimension	1com-2com	1com-2com	1com-2com
D & M planks	.....	1com-2com	1com-2com	1com-2com
Bracing	Boards	1com-2com	1com-2com	1com-2com
Tanks and supports:				
Sills	Timbers	**Sel-Com	.....	**Sel-Com
Posts	Posts	**Sel-Com	.....	**Sel-Com
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Bracing	Plank	**Sel-Com	.....	**Sel-Com
Joists	Joist	**Sel-Com	.....	**Sel-Com
D & M flooring	Heavy flooring			
*Staves				
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof	Shiplap	1com-2com	1com-2com	1com-2com
Ladders, etc	.....	C&Btr-1com	.....	C&Btr-1com
Frost box material	Shiplap	1com-2com	.....	1com-2com
Docks and wharves:				
Timber sheet piling	Timbers	**Sel-Com	.....	**Sel-Com
Timber in cribs	Timbers	**Sel-Com	.....	**Sel-Com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red fir: Western Pine Manufacturers Association; Douglas fir; California White and Sugar Pine Manufacturers Association	White fir: Western Pine Manufacturers Association and California White and Sugar Pine Manufacturers Association	Western larch: Western Pine Manufacturers Association
Docks and wharves, continued				
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Bracing	Plank	**Sel-**Com**	.....	**Sel-**Com**
Guard timber	Timbers	**Sel-**Com**	.....	**Sel-**Com**
Ties	Timbers	**Sel-Com	.....	**Sel-Com
Plank decking	Plank	**Sel-Com	.....	**Sel-Com
Mooring posts	Timbers	**Sel-Com	.....	**Sel-Com
Fenders and wales	Timbers	**Sel-**Com**	.....	**Sel-**Com**
Coaling and ore stations:				
Sills and mud sills	Timbers	**Sel-**Com**	.....	**Sel-**Com**
Posts	Posts	**Sel-Com	.....	**Sel-Com
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Bracing	Plank	**Sel-**Com**	.....	**Sel-**Com**
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Joists	Joists	**Sel-Com	.....	**Sel-Com
Bin lining	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Flooring	Boards	**1com**-2com	**1com**-2com	**1com**-2com
Chutes	Boards	**1com**-2com	**1com**-2com	**1com**-2com
Decking	Boards	**1com**-2com	**1com**-2com	**1com**-2com
Coal pockets and bins	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roofing	Shiplap	1com-**2com**	1com-**2com**	1com-**2com**
Tunnels:				
Posts	Posts	**Sel-Com	.....	**Sel-Com
Sills	Timbers	**Sel-Com	.....	**Sel-Com
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Segments	Timbers	**Sel-Com	.....	**Sel-Com
Lagging	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Struts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Caisson	Timbers	**Sel-Com	.....	**Sel-Com

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the left and alternate grades of lower quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the associations publishing rules covering the various species are shown in the column headings.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red fir: Western Pine Manufacturers Association; Douglas fir; California White and Sugar Pine Manufacturers Association	White fir: Western Pine Manufacturers Association and California White and Sugar Pine Manufacturers Association	Western larch: Western Pine Manufacturers Association
Station buildings, passenger, freight, platform shelters:				
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Sills	Timbers	**Sel-Com	.....	**Sel-Com
Posts	Timbers	**Sel-Com	.....	**Sel-Com
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Joists	Joists	**Sel-Com	.....	**Sel-Com
Bridging	Boards	2com-3com	2com-3com	2com-3com
Subflooring	Shiplap	1com-2com	1com-2com	1com-2com
Finish flooring (natural finish)	Flooring	*C&Btr(E)	.....	*C&Btr(E)
Finish flooring (paint finish)	Flooring	C&Btr	.....	C&Btr
Studding and plates	Dimension	1com-2com	1com-2com	1com-2com
Sheathing	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Furring	Strips	1com-2com-3com	1com-2com-3com	1com-2com-3com
Siding	Siding	C&Btr-D	C&Btr-D	C&Btr-D
Ceiling (natural finish)	Ceiling	*C&Btr	.....	*C&Btr
Ceiling (paint finish)	Ceiling	C&Btr	C&Btr	C&Btr
Truss timbers	Dimension	1com-2com	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Shingles (roof)	Shingles			
Shingles (side walls)	Shingles			
Door and window frames	Finish lumber	C&Btr	C&Btr	C&Btr
Outside finish lumber	Finish lumber	C&Btr-D	C&Btr-D	C&Btr-D
Inside finish (natural finish)	Finish lumber	C&Btr	.....	C&Btr
Inside finish (paint finish)	Finish lumber	C&Btr	C&Btr	C&Btr
Millwork (moldings)	Molding			
Millwork (stairs)	Finish lumber	C&Btr	C&Btr	C&Btr
Partitions	Partition	C&Btr-D	C&Btr-D	C&Btr-D
Shelving	Finish lumber	C-D	C-D	C-D
Engine houses and machine shops:				
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Sills	Timbers	**Sel-Com	.....	**Sel-Com
Posts	Timbers	**Sel-Com	.....	**Sel-Com
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Joists	Joists	**Sel-Com	.....	**Sel-Com
Bridging	Boards	2com-3com	2com-3com	2com-3com
Flooring	Dimension	1com	1com	1com
Pit timbers	Timbers	**Sel-Com	.....	**Sel-Com
Studding	Dimension	1com-2com	1com-2com	1com-2com
Furring	Strips	1com-2com-3com	1com-2com-3com	1com-2com-3com
Siding	Siding	C&Btr-D	C&Btr-D	C&Btr-D
Ceiling	Ceiling	C&Btr-D	C&Btr-D	C&Btr-D
Truss lumber	Dimension	1com-2com	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Shingles	Shingles			
Door and window frames	Finish lumber	C&Btr	C&Btr	C&Btr
Outside finish lumber	Finish lumber	C&Btr-D	C&Btr-D	C&Btr-D
Inside finish lumber	Finish lumber	C&Btr	C&Btr	C&Btr
Millwork	Finish lumber	C&Btr	C&Btr	C&Btr
Sleepers	Dimension	1com-2com	1com-2com	1com-2com
Section houses and small buildings:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com	1com-2com
Caps	Dimension	1com-2com	1com-2com	1com-2com
Joists (section houses)	Dimension	1com	1com	1com
Joists (small buildings)	Joist	**Sel-Com	.....	**Sel-Com
Bridging	Boards	2com-3com	2com-3com	2com-3com
Subflooring	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red fir: Western Pine Manufacturers Association; Douglas fir; California White and Sugar Pine Manufacturers Association	White fir: Western Pine Manufacturers Association and California White and Sugar Pine Manufacturers Association	Western larch: Western Pine Manufacturers Association
Section houses and small buildings, continued:				
Finish flooring (natural finish)	Flooring	*C&Btr	.....	*C&Btr(E)
Finish flooring (paint finish)	Flooring	C&Btr	.....	C&Btr
Studding and plates	Dimension	1com-2com	1com-2com	1com-2com
Sheathing	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Furring	Strips	1com-2com-3com	1com-2com-3com	1com-2com-3com
Siding	Siding	C&Btr-D	C&Btr-D	C&Btr-D
Ceiling	Ceiling	C&Btr-D	C&Btr-D	C&Btr-D
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Shingles	Shingles			
Door and window frames	Finish lumber	C&Btr	C&Btr	C&Btr
Outside finish lumber	Finish lumber	C&Btr-D	C&Btr-D	C&Btr-D
Inside finish lumber	Finish lumber	C&Btr	C&Btr	C&Btr
Millwork	Finish lumber	C&Btr	C&Btr	C&Btr
Warehouses and ice houses:				
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Sills	Timbers	**Sel-Com	.....	**Sel-Com
Posts	Timbers	**Sel-Com	.....	**Sel-Com
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Joists (warehouses)	Joists	**Sel-Com	.....	**Sel-Com
Joists (ice houses)	Dimension	1com	1com	1com
Bridging	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Subflooring	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Finish flooring	Flooring	C&Btr	.....	C&Btr
Studding and plates	Dimension	1com-2com	1com-2com	1com-2com
Sheathing	Ship lap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Furring	Strips	1com-2com-3com	1com-2com-3com	1com-2com-3com
Siding	Siding	C&Btr-D	C&Btr-D	C&Btr-D
Ceiling	Ceiling	C&Btr-D	C&Btr-D	C&Btr-D
Truss timbers	Dimension	1com-2com	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Shingles	Shingles			
Door and window frames	Finish lumber	C&Btr	C&Btr	C&Btr
Outside finish lumber	Finish lumber	C&Btr-D	C&Btr-D	C&Btr-D
Inside finish lumber	Finish lumber	C&Btr	C&Btr	C&Btr
Millwork	Finish lumber	C&Btr	C&Btr	C&Btr
Sleepers	Strips	1com-2com-3com	1com-2com-3com	1com-2com-3com

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the left, and alternate grades of lower quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the associations publishing rules covering the various species are shown in the column headings.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red fir: Western Pine Manufacturers Association; Douglas fir; California White and Sugar Pine Manufacturers Association	White fir: Western Pine Manufacturers Association and California White and Sugar Pine Manufacturers Association	Western larch: Western Pine Manufacturers Association
Miscellaneous roadway material				
Crossing plank	Dimension	1com-2com	.....	1com-2com
Platforms:				
Posts	Dimension	1com-2com	.....	1com-2com
Caps	Dimension	1com-2com	.....	1com-2com
Sills	Dimension	1com-2com	.....	1com-2com
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Joists	Joists	**Sel-Com	.....	**Sel-Com
Bridging	Boards	2com-3com	2com-3com	2com-3com
Planking	Dimension	1com-2com	.....	1com-2com
Railing	Dimension	1com-2com	.....	1com-2com
Steps	Boards	1com-2com	.....	1com-2com
Skids	Dimension	1com-2com	1com-2com	1com-2com
Stock guards:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Ties	Timbers	**Sel-Com	.....	**Sel-Com
Wing fences and aprons	Boards	1com-2com	1com-2com	1com-2com
Slats	Boards	1com-2com	1com-2com	1com-2com
Fillers	Boards	1com-2com	1com-2com	1com-2com
Signs and posts:				
Posts	Dimension	1com-2com	.....	1com-2com
Bracing	Dimension	1com-2com-3com	1com-2com	1com-2com-3com
Sign boards	Finish lumber	C&Btr-1com	C&Btr-1com	
Molding	Molding			
Fencing, including snow fence:				
Posts	Dimension	1com-2com	.....	1com-2com
Bracing	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Stringers	Dimension	1com-2com	1com	1com-2com
Fence boards	Boards	1com-2com	1com-2com	1com-2com
Gate materials	Boards	1com-2com	1com-2com	1com-2com
Stakes	Boards	1com-2com	1com-2com	1com-2com
Culverts and drains:				
Sills	Timbers	**Sel-Com	.....	**Sel-Com
Bracing	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Timbers	Timbers	**Sel-Com	.....	**Sel-Com
Planking	Dimension	1com-2com-3com	1com-2com	1com-2com-3com
Grillage	Timbers	**Sel-Com	.....	**Sel-Com
Stock pens:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com	1com-2com
Fencing	Dimension	1com-2com	1com-2com	1com-2com
Studding	Dimension	1com-2com	1com-2com	1com-2com
Sheathing	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Shingles	Shingles			
Outside finish lumber	Finish lumber	C&Btr-D	C&Btr-D	C&Btr-D
Poles	Timbers	**Sel-Com	.....	**Sel-Com
Conduits	Dimension	1com-2com	.....	1com-2com
Bumping blocks	Timbers	**Sel-Com	.....	**Sel-Com
Railroad cars[1]				
Battens, door	Strips	1com-2com	.....	1com-2com
Beams, needle	Timbers			
Belt rail	Boards	1com		
Boards, card, legend, number	Finish lumber			
Braces	Joists			
Car lines	Dimension	1com	.....	1com
Decking or flooring	Heavy flooring or decking			
Open cars	.....	.....	.....	C&Btr-D-1com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Red fir — Western Pine Manufacturers Association; Douglas fir; California White and Sugar Pine Manufacturers Association	White fir — Western Pine Manufacturers Association and California White and Sugar Pine Manufacturers Association	Western larch — Western Pine Manufacturers Association
Decking or flooring continued				
Box cars	.....	.....	.....	C&Btr-D-1com
Stock cars	.....	.....	.....	C&Btr-D-1com
Subflooring	.....	1com	.....	1com
Door header	Dimension	1com	.....	1com
Door, grain	Boards	1com	1com	1com
Door, side	Siding	C&Btr-1com		
Fascia	Finish lumber	C&Btr		
Framing, car	Joists			
Framing, box car side door	Joists	**Sel-Com	.....	**Sel-Com
Lining	Lining			
Refrigerator and box car without siding	.....	C&Btr		
Refrigerator and box car with siding	.....	1com		
Plank, side and end	Plank	1com	.....	1com
Posts, corner	Joist			
Posts, door	Joist			
Roofing	Roofing			
Single board and outside double board	.....	C&Btr-1com		
Double board inside	.....	1com		
Running boards	Finish lumber	C&Btr		
Ridge pole	Dimension	1com		
Siding or sheathing	Siding	C&Btr-1com		
Sills	Stringers			
Stakes	Dimension	1com	.....	1com

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its Bull. 284, dated February 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the associations publishing rules covering the various species are shown in the column headings.

[1] First grade recommended is for new cars; second, for repairs.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Industrial buildings	Item	Red fir: Western Pine Manufacturers Association; Douglas Fir; California White and Sugar Pine Manufacturers Association	White fir: Western Pine Manufacturers Association and California White and Sugar Pine Manufacturers Association	Western larch: Western Pine Manufacturers Association
Posts	Timbers	**Sel-Com	.....	**Sel-Com
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Girders	Beams	**Sel-Com	.....	**Sel-Com
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Heavy joists	Joists	**Sel-Com	.....	**Sel-Com
Heavy flooring	Heavy flooring	1com	.....	1com
Plates	Joists	**Sel-com	.....	**Sel-Com
Truss members	Dimension	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof planking	Dimension	1com-2com	1com-2com	1com-2com
Bridging	Boards	2com-3com	2com-3com	2com-3com
Sills	Timbers	**Sel-Com	.....	**Sel-Com
Airplane hangars				
Framing:				
Sills	Dimension	1com-2com	1com-2com	1com-2com
Studs	Dimension	1com-2com	1com-2com	1com-2com
Plates	Dimension	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Truss members	Dimension	1com-2com	1com-2com	1com-2com
Siding	Siding	C&Btr-D	C&Btr-D	C&Btr-D
Sheathing, wall and roof	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Trim, exterior and interior window and door frames	Finish lumber	C&Btr-D	C&Btr-D	C&Btr-D
Highway uses				
Bridges:				
Posts or columns	Posts	**Sel-Com	.....	**Sel-Com
Mud sills	Timbers	**Sel-Com	.....	**Sel-Com
Sills	Timbers	**Sel-Com	.....	**Sel-Com
Caps	Timbers	**Sel-Com	.....	**Sel-Com
Bracing	Joists	**Sel-Com	.....	**Sel-Com
Truss members	Joists	**Sel-Com	.....	**Sel-Com
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Floor beams	Stringers	**Sel-Com	.....	**Sel-Com
Bridging	Dimension	1com-2com	1com-2com	1com-2com
Nailing strips	Dimension	1com-2com	1com-2com	1com-2com
Flooring	Plank	**Sel-Com	.....	**Sel-Com
Retaining pieces	Timbers	**Sel-Com	.....	**Sel-Com
Wheel guards	Timbers	**Sel-Com	.....	**Sel-Com
Rail posts	Posts	1com	.....	1com
Railing	Dimension	1com	.....	1com
Fire stops	Dimension	1com-2com	1com-2com	1com-2com
Stadia				
Posts	Posts	**Sel-Com	.....	**Sel-Com
Stringers	Stringers	**Sel-Com	.....	**Sel-Com
Braces (diagonal)	Joists	**Sel-Com	.....	**Sel-Com
Seats	Finish lumber	C&Btr		
Back rests	Dimension	1com	.....	1com
Seat supports	Dimension	1com	.....	1com
Planking, ramps, decks	Dimension	1com	.....	1com
Railing	Dimension	1com	.....	1com
Railposts	Dimension	1com	.....	1com
Walls, front, boxes, press box	Finish lumber (pattern)	C&Btr-D-1com	C&Btr-D-1com	C&Btr-D-1com

NOTE.—The grades in boldface type are suitable for the use under ordinary conditions. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for use where the requirements are not exacting are shown to the right.

Association standard grades are shown except in cases where the association concerned does not publish structural grades. In such cases, the American Lumber Standards structural grades are used and are indicated by two asterisks (**).

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Dwelling construction	Western red cedar	Douglas fir	West Coast hemlock	Sitka spruce
	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association
Interior uses:				
Finish and woodwork (natural finish)	**B&Btr**	**B&Btr**	**B&Btr**	**B&Btr**
Finish and woodwork (paint finish)	**B&Btr**	**B&Btr-C**	**B&Btr-C**	**B&Btr-C**
Moldings (natural and paint finish)	**B&Btr**	**B&Btr**	**B&Btr**	**B&Btr**
Flooring:				
Living and dining room, hall, etc.	.....	**A(E)-B(E)**-B&Btr(F)-C(E)	**A(E)-B(E)**-B&Btr(F)-C(E)	
Bedroom	.....	B(E)-**B&Btr(F)**-C(E)	B(E)-**B&Btr(F)**-C(E)	
Kitchen (not to be covered)	.....	**B(E)**-B&Btr(F)-C(E)	**B(E)**-B&Btr(F)-C(E)	
Kitchen (to be covered)	.....	B&Btr(F)-**C(E or F)**-D(E or F)	B&Btr(F)-**C(E or F)**-D(E or F)	
Shelving	B&Btr-Selcom-1com	B&Btr-Selcom-1com	B&Btr-Selcom-1com	B&Btr-**Selcom-1com**
Stepping	.....	**A(E)-B(E)**-B&Btr(F)-C(E)	**A(E)-B(E)**-B&Btr(F)-C(E)	**B&Btr-C**
Exterior uses:				
Window and door frames	**B&Btr-1com**	**B&Btr-1com**	**B&Btr-1com**	**B&Btr-1com**
Bungalow and colonial siding	**B&Btr**	**B&Btr**	**B&Btr**	**B&Btr**
Bevel Siding	**Cl-A-B**	A-B-C	**B&Btr-C**	A-B-C
Rustic and drop siding	.....	**B&Btr-C**	**B&Btr-C**	
Porch flooring (covered)	**B&Btr-C**	B(E or F)-**C(E or F)**-D(E or F)	B(E or F)-**C(E or F)**-D(E or F)	
Porch flooring (uncovered)	**B&Btr-C**	**B(E)**-B&Btr(F)-C(E)	**B(E)**-B&Btr(F)-C(E)	
Stepping	**B&Btr-C**	**B(E)**-B&Btr(F)-C(E)	**B(E)**-B&Btr(F)-C(E)	**B&Btr-C**
Exterior trim	**B&Btr**	**B&Btr-C**	**B&Btr-C**	**B&Btr-C**
Sheathing, etc.:				
Wall sheathing	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Roof sheathing	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Subflooring	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Framing:				
Posts	.....	**Str-1com**		
Girders	.....	**Str-1com**		
Sills	**1com**	**1com**		
Joists and rafters	.....	**1com**-2com	**1com**-2com	
Plates, headers, braces	.....	1com-**2com**	1com-**2com**	
Studs	.....	1com-**2com**-3com	1com-**2com**-3com	
Cross-bridging, ribbons, ties	.....	1com-**2com**-3com	1com-**2com**-3com	

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Farm uses	Western red cedar	Douglas fir	West Coast hemlock	Sitka spruce
	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association
Barns and other large buildings:				
Framing:				
Posts	.....	Str-**1com**		
Girders	.....	Str-1com		
Sills	**1com**	1com		
Joists, rafters, trusses, plates and headers, braces, collar beams	.....	Str-**1com**-2com	**1com**-2com	**1com**-2com
Studs	.....	1com-**2com**	1com-**2com**	1com-**2com**
Cross-bridging, ribbons	.....	1com-**2com**	1com-**2com**	1com-**2com**
Drop siding	.....	**B&Btr-C**	**B&Btr-C**	
	.....	C-D-**1com**-2com	C-D-**1com**-2com	C-D-**1com**-2com
Barn boards	Sel Com-**1com**-2com	Selcom-**1com**-2com	Selcom-**1com**-2com	Selcom-**1com**-2com
Battens	Battens	Battens	Battens	Battens
Exterior trim and doors	**B&Btr**	**B&Btr-C**	**B&Btr-C**	**B&Btr-C**
Sheathing, roof and wall	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Heavy flooring	**1com**	**1com**		
Subflooring	.....	1com-**2com**	1com-**2com**	1com-**2com**
Stanchions and stalls	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Mangers	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Small farm structures (separate and lean-to sheds, stock shelters, hog, poultry, and dairy houses, small granaries):				
Framing:				
Posts, girders, sills, joists, rafters	**1com**	1com-**2com**	1com-**2com**	1com-**2com**
Studs, plates, headers, braces, collar ties, cross-bridging, ribbons	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Siding, barn boards, exterior trim	Selcom-**1com**-2com	Selcom-**1com**-2com	Selcom-**1com**-2com	Selcom-**1com**-2com
Flooring	.....	C-**1com**-2com	C-**1com**-2com	B&Btr-**1com**-2com
Sheathing (covered)	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Inside equipment (roosts, nests, racks, shelving)	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Corn cribbing	Selcom-**1com**-2com	Selcom-**1com**-2com	Selcom-**1com**-2com	Selcom-**1com**-2com
Gates and fencing	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

General uses related to building construction	Western red cedar	Douglas fir	West Coast hemlock	Sitka spruce
	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association
Scaffolding and Staging	.....	Str-**1com**-2com	**1com**-2com	**1com**-2com
Concrete forms:				
Boards	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Western red cedar	Douglas fir	West Coast hemlock	Sitka spruce
		West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association
Bridge and construction timber:					
Combination and Howe truss spans:					
Compression members	Posts and timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Tension	Joist and plank	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Diagonals subject to reverse stress	Posts and timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Floor beams and stringers	Beams and stringers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Ties	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Guard timbers	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Railing	Dimension	1com	1com	1com	1com
Stiffeners	Dimension	1com	1com	1com	1com
Splices	Dimension	1com	1com	1com	1com
Nailing strips	Dimension	1com	1com	1com	1com
Grillage	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Deck plank	Dimension	1com	1com	1com	1com
Bridging	Boards	1com-2com	1com-2com	1com-2com	1com-2com
Pile and frame trestles:					
Sills and mud sills	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Posts	Posts	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Sash bracing	Plank	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Cross-bracing	Plank	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com

Pile and frame trestles, continued:					
Longitudinal bracing	Plank	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Girts	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
End planks	Planks	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Ties	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Guard timbers	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Planking for ballasted deck	Plank	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Railing	Dimension	1com	1com	1com	1com
Falsework:					
Sills and mud sills	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Posts	Posts	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Truss timbers	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Centering	Dimension	1com	1com	1com	1com
Lagging	Dimension	1com	1com	1com	1com
Bracing	Plank	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Wedges	Dimension	1com	1com	1com	1com
Scaffolding	Dimension	.....	1com-2com	1com-2com	1com-2com
Concrete forms:					
Dimension lumber	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
D & M planks	.....	1com-2com	1com-2com	1com-2com	1com-2com
Bracing	Boards	1com-2com	1com-2com	1com-2com	1com-2com
Tanks and supports:					
Sills	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Posts	Posts	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Bracing	Plank	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Joists	Joist	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
D & M flooring	Heavy flooring	.....	C		
*Staves		*B&Btr	*Tank Stock		
Rafters	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Roof	Shiplap	1com-2com	1com-2com	1com-2com	1com-2com
Ladders, etc.	.....	.....	Ladder Stk-1com	Ladder Stk-1com	Ladder Stk-1com
Frostbox material	Shiplap	1com-2com	1com-2com	1com-2com	1com-2com
Docks and wharves:					
Timber sheet piling	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Western red cedar	Douglas fir	West Coast hemlock	Sitka spruce
		West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association
Docks and wharves, continued:					
Timber in cribs	Timbers	**Sel-Com	Str-**No1com**	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	**DseStr-Str-**No1com	**Sel-Com	**Sel-Com
Bracing	Plank	**Sel-Com	Str-**No1com**	**Sel-Com	**Sel-Com
Guard timber	Timbers	**Sel-Com	Str-**No1com**	**Sel-Com	**Sel-Com
Ties	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Plank decking	Plank	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Mooring posts	Timbers	.....	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Fenders and wales	Timbers	**Sel-Com	Str-**No1com**	**Sel-Com	**Sel-Com
Coaling and ore stations:					
Sills and mud sills	Timbers	**Sel-Com	Str-**No1com**	**Sel-Com	**Sel-Com
Posts	Posts	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Bracing	Plank	**Sel-Com	Str-**No1com**	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	**DseStr-Str-**No1com	**Sel-Com	**Sel-Com
Joists	Joists	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Bin lining	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Flooring	Boards	.....	**1com**-2com	**1com**-2com	**1com**-2com
Chutes	Boards	.....	**1com**-2com	**1com**-2com	**1com**-2com
Decking	Boards	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Coal pockets and bins	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Roofing	Shiplap	**1com**-2com	1com-**2com**	1com-**2com**	1com-**2com**
Tunnels:					
Posts	Posts	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Sills	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Segments	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com

Tunnels, continued:					
Lagging	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Struts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Caisson	Timbers	**Sel-com	DseStr-Str-No1com	**Sel-Com	**Sel-Com

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Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the left, and alternate grades of lower quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Western red cedar	Douglas fir	West Coast hemlock	Sitka spruce
		West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association
Station buildings, passenger, freight, platform shelters:					
Caps	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Sills	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Posts	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	DsStr-Str-No1com	**Sel-Com	**Sel-Com
Joists	Joists	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Bridging	Boards	1com-2com	2com-3com	2com-3com	2com-3Com
Subflooring	Shiplap	1com-2com	1com-2com	1com-2com	1com-2com
Finish flooring (natural finish)	Flooring	.....	A(E)-B(E)-B&Btr(F)-C	B(E)-B&Btr(F)	
Finish flooring (paint finish)	Flooring	.....	B&Btr(F)-C-D	B&Btr(F)	
Studding and plates	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Sheathing	Shiplap	1com-2com	1com-2com	1com-2com	1com-2com
Furring	Strips	1com-2com	1com-2com	1com-2com	1com-2com
Siding	Siding	Cl-A-B	A-B-C	B&Btr-C	B-C (bevel)
Ceiling (natural finish)	Ceiling	.....	B&Btr	B&Btr	B&Btr
Ceiling (paint finish)	Ceiling	.....	C	C	*B&Btr
Truss timbers	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com	1com-2com	1com-2com	1com-2com
Shingles (roof)	Shingles	A			

Station buildings, passenger, freight, platform shelters, continued:					
Shingles (side walls)	Shingles	B			
Door and window frames	Finish lumber	B&Btr	B&Btr-C	B&Btr-C	B&Btr-C
Outside finish lumber	Finish lumber	*B&Btr	B&Btr-C	B&Btr-C	B&Btr-C
Inside finish (natural)	Finish lumber	B&Btr	B&Btr-C	B&Btr	B&Btr
Inside finish (paint)	Finish lumber	B&Btr	B&Btr-C	C-D	B&Btr-C
Millwork (moldings)	Molding	B&Btr	B&Btr	B&Btr	B&Btr
Millwork (stairs)	Finish lumber	.....	B&Btr-C	B&Btr-C	B&Btr-C
Partitions	Partition	.....	B&Btr-C	B&Btr-C-D	B&Btr
Shelving	Finish lumber	B&Btr-Selcom	B&Btr-C		
Engine houses and machine shops:					
Caps	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Sills	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Posts	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Joists	Joists	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Bridging	Boards	1com-2com	2com-3com	2com-3com	2com-3com
Flooring	Dimension	1com	1com	1com	
Pit timbers	Timbers	**Sel-com	Str-No1com	**Sel-Com	**Sel-Com
Studding	Dimension	.....	1com-2com	1com-2com	1com-2com
Furring	Strips	1com-2com	1com-2com	1com-2com	1com-2com
Siding	Siding	*Cl-A-B	B&Btr-C	B&Btr-C-D	B-C
Ceiling	Ceiling	.....	B&Btr-C	B&Btr-C-D	*B&Btr
Truss lumber	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com	1com-2com	1com-2com	1com-2com
Shingles	Shingles	A			
Door and window frames	Finish lumber	B&Btr	B&Btr-C	B&Btr-C	B&Btr-C
Outside finish lumber	Finish lumber	*B&Btr	B&Btr-C	B&Btr	B&Btr-C
Inside finish lumber	Finish lumber	B&Btr	B&Btr-C	B&Btr-C-D	B&Btr-C
Millwork	Finish lumber	B&Btr	B&Btr-C	B&Btr-C-D	B&Btr-C
Sleepers	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Section houses and small buildings:					
Posts	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Caps	Dimension	1com-2com	1com-2com	1com-2com	1com-2com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Western red cedar	Douglas fir	West Coast hemlock	Sitka spruce
		West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association
Section houses and small buildings, continued:					
Joists (section houses)	Dimension	1com-**2com**	**1com**	**1com**	**1com**
Joists (small buildings)	Joist	**Sel-Com	Str-**No1com**	**Sel-Com	**Sel-Com
Bridging	Boards	1com-**2com**	2com-**3com**	2com-**3com**	2com-**3com**
Subflooring	Shiplap	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Finish flooring (natural finish)	Flooring	.....	(AE)-B(E)-B&Btr(F)-C	B(E)-B&Btr(F)	
Finish flooring (paint finish)	Flooring	.....	B&Btr(F)-C-D	B&Btr(F)	
Studding and plates	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Shiplap	**1com**-2com	1com-**2com**	1com-**2com**	1com-**2com**
Furring	Strips	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Siding	Siding	*Cl-A-B	B&Btr-C	B&Btr-C-D	B-C
Ceiling	Ceiling	.....	B&Btr-**C**	B&Btr-**C-D**	***B&Btr**
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Roof boards	Shiplap	**1com**	1com-**2com**	1com-**2com**	1com-**2com**
Shingles	Shingles	**A**			
Door and window frames	Finish	**B&Btr**	B&Btr-C	B&Btr-C	B&Btr-C
Outside finish lumber	Finish lumber	***B&Btr**	B&Btr-C	B&Btr-C	B&Btr-C
Inside finish lumber	Finish lumber	**B&Btr**	B&Btr-C	B&Btr-C-D	**B&Btr-C**
Millwork	Finish lumber	.....	B&Btr-C	B&Btr-C-D	**B&Btr-C**
Warehouses and ice houses:					
Caps	Timbers	**Sel-Com	Str-**No1com**	**Sel-Com	**Sel-Com**
Sills	Timbers	**Sel-Com	Str-**No1com**	**Sel-Com	**Sel-Com**

Warehouses and ice houses, continued:					
Posts	Timbers	**Sel-**Com	Str-No1com	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Joists (warehouses)	Joists	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Joists (ice houses)	Dimension	1com	**1com**	**1com**	**1com**
Bridging	Boards	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Subflooring	Boards	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Finish flooring	Flooring	.....	**B(E)-B&Btr(F)-C**	**B&Btr(F)**	
Studding and plates	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Shiplap	**1com**	1com-**2com**	1com-**2com**	1com-**2com**
Furring	Strips	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Siding	Siding	*Cl-A-B	B&Btr-C	B&Btr-C-D	B-C
Ceiling	Ceiling	.....	B&Btr-C	B&Btr-C-D	*B&Btr
Truss timbers	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Purlins	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Roof boards	Shiplap	**1com**-2com	1com-**2com**	1com-**2com**	1com-**2com**
Shingles	Shingles	**A**			
Door and window frames	Finish lumber	**B&Btr**	B&Btr-C	B&Btr-C	B&Btr-C
Outside finish lumber	Finish lumber	**B&Btr**	B&Btr-C	B&Btr-C	B&Btr-C
Inside finish lumber	Finish lumber	**B&Btr**	B&Btr-C	B&Btr-C-D	B&Btr-C
Millwork	Finish lumber	**B&Btr**	B&Btr-C	B&Btr-C-D	B&Btr-C
Sleepers	Strips	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses		Western red cedar	Douglas fir	West Coast hemlock	Sitka spruce
	Item	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association
Miscellaneous roadway material					
Crossing plank	Dimension	1com-2com	1com-2com	1com-2com	
Platforms:					
Posts	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Caps	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Stringers	Stringers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Joists	Joists	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Bridging	Boards	1com-2com	2com-3com	2com-3com	2com-3com
Planking	Dimension	1com-2com	1com-2com	1com-2com	
Railing	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Steps	Boards	.....	1com	1com-	
Skids	Dimension	1com-2com	1com-2com	1com-2com	
Stock Guards:					
Posts	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Ties	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Wing fences and aprons	Boards	1com-2com	1com-2com	1com-2com	1com-2com
Slats	Boards	1com-2com	1com-2com	1com-2com	1com-2com
Fillers	Boards	1com-2com	1com-2com	1com-2com	1com-2com
Signs and posts:					
Posts	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Bracing	Dimension	1com-2com	1com-2com-3com	1com-2com-3com	1com-2com
Sign boards	Finish lumber	*B&Btr	B&Btr-C	B&Btr-C	B&Btr-C
Molding	Molding	*B&Btr	*B&Btr	*B&Btr	*B&Btr
Fencing, including snow fence:					
Posts	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Bracing	Boards	1com-2com	1com-2com	1com-2com	1com-2com
Stringers	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Fence boards	Boards	1com-2com	1com-2com	1com-2com	1com-2com
Gate materials	Boards	1com-2com	1com-2com	1com-2com	1com-2com
Stakes	Boards	1com	1com-2com	1com-2com	1com-2com
Culverts and drains:					
Sills	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Bracing	Boards	1com-2com	1com-2com	1com-2com	1com-2com
Timbers	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Planking	Dimension	1com-2com	1com-2com-3com	1com-2com-3com	1com-2com
Grillage	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Stock pens:					
Posts	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Fencing	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Studding	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Sheathing	Shiplap	1com	1com-2com	1com-2com	1com-2com

Roof boards	Shiplap	**1com**	1com-**2com**	1com-**2com**	1com-**2com**
Shingles	Shingles	**A-B**			
Outside finish lumber	Finish lumber	**B&Btr**	B&Btr-**C**	B&Btr-**C**	B&Btr-**C**
Poles	Timbers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Conduits	Dimension	Trunking and capping	**1com**-2com	**1com**-2com	
Bumping blocks	Timbers	.....	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Railroad uses					
Railroad cars[1]					
Battens, door	Strips	.....	**1com**-2com	1com-2com	**1com**-2com
Beams, needle	Timbers	.....	DseStr-Str		
Belt rail	Boards	.....	**1com**-2com		
Boards, card, legend, number	Finish lumber	.....	B&Btr-**C**	.....	B&Btr-**C**
Braces	Joists	.....	DseStr-Str		
Carlines	Dimension	.....	**1com**	**1com**	
Decking or flooring	Heavy flooring or decking				
Open cars		.....	B&Btr-C-1com		
Box cars		.....	B&Btr-C-1com		
Stock cars		B&Btr-1com	B&Btr-C-1com		
Sub-flooring		**1com**	**1com**		
Door header	Dimension	.....	**1com**		
Door, grain	Boards	.....	**1com**	**1com**	**1com**
Door, side	Siding	.....	B&Btr-1com	B&Btr-1com	
Fascia	Finish lumber	B&Btr	B&Btr	B&Btr	
Framing, car	Joists	.....	DseStr-Str		
Framing, box car side door	Joists	.....	Str-No1com		
Lining	Lining				
Refrigerator and box car without siding		.....	B&Btr	B&Btr	
Refrigerator and box car with siding		.....	**1com**	**1com**	
Plank, side and end	Plank	.....	**1com**		
Posts, corner	Joist	.....	B&Btr-1com		
Posts, door	Joist	.....	B&Btr-1com		
Roofing	Roofing				
Single board and outside double board		.....	B&Btr-1com	B&Btr-1com	
Double board inside		**1com**	**1com**	**1com**	**1com**
Running boards	Finish lumber	.....	B&Btr		
Ridge pole	Dimension	.....	**1com**		
Siding or sheathing	Siding	.....	B&Btr-1com	B&Btr-1com	B&Btr-1com
Sills	Stringers	.....	DseStr-Str		
Stakes	Dimension	.....	**1com**		

[1] First grade recommended is for new cars; second, for repairs.

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Industrial buildings	Item	Western red cedar	Douglas fir	West Coast hemlock	Sitka spruce
		West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association	West Coast Lumbermen's Association
Posts	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Girders	Beams	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Heavy joists	Joists	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Heavy flooring	Heavy flooring	1com	1com-Block	1com	
Plates	Joists	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Truss members	Dimension	1com-2com	Str-1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Roof planking	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Bridging	Boards	1com-2com	2com-3com	2com-3com	2com-3com
Sills	Timbers	**Sel-Com	Str-No1com		
Airplane hangars					
Framing:					
Sills	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Studs	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Plates	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Truss members	Dimension	1com-2com	Str-1com-2com	1com-2com	1com-2com
Siding	Siding	Cl-A-B	B&Btr-C	B&Btr-C-D	B-C
Sheathing, wall and roof	Shiplap	1com-2com	1com-2com	1com-2com	1com-2com
Trim, exterior and interior, window and door frames	Finish lumber	B&Btr	B&Btr-C	.....	B&Btr-C

Highway uses					
Bridges:					
Posts or columns	Posts	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Mud sills	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Sills	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Caps	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Bracing	Joists	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Truss members	Joists	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Stringers	Stringers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Floor beams	Stringers	**Sel-Com	DseStr-Str-No1com	**Sel-Com	**Sel-Com
Bridging	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Nailing strips	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Flooring	Plank	**Sel-Com	Str-No1com	**Sel-Com	Sel-Com
Retaining pieces	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Wheel guards	Timbers	**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Rail posts	Posts	1com	1com	1com	1com
Railing	Dimension	1com	1com	1com	1com
Fire stops	Dimension	1com-2com	1com-2com	1com-2com	1com-2com
Stadia					
Posts	Posts	..**Sel-Com	Str-No1com	**Sel-Com	**Sel-Com
Stringers	Stringers	..**Sel-Com	DseStr-Str-No1com	**Sel-Com	Sel-Com
Braces, diagonal	Joists	..**Sel-Com	str-No1com	**Sel-Com	Sel-Com
Seats	Finish lumber	.....	B&Btr		
Back rests	Dimension	1com	1com	1com	1com
Seat supports	Dimension	1com	1com	1com	1com
Planking, ramps, decks	Dimension	1com	1com	1com	
Railing	Dimension	1com	1com	1com	
Railposts	Dimension	1com	1com	1com	
Walls, front, boxes, press box	Finish lumber (pattern)	Cl-A-B	B&Btr-C-Selcom1com	B&Btr-C-D	B-C-1com

NOTE.—The grades in boldface type are suitable for the use under ordinary conditions. Alternate grades for unusually high quality of construction are shown to the left and alternate grades for use where the requirements are not exacting are shown to the right.

Association standard grades are shown except in cases where the association concerned does not publish structural grades. In such cases, the American Lumber Standards structural grades are used and are indicated by two asterisks (**).

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Dwelling construction	Longleaf southern pine	Shortleaf southern pine
	Southern Pine Association	Southern Pine Association
Interior uses:		
Finish and woodwork (natural finish)	**B&Btr**	**B&Btr**
Finish and woodwork (paint finish)	**1com**-2com	**1com**-2com
Moldings (natural and paint finish)	**B&Btr**	**B&Btr**
Flooring:		
Living and dining room, hall, etc	**B&Btr(HtE)-B&Btr(E)-B&Btr(F)**-1com(E)	**B&Btr(HtE)-B&Btr(E)-B&Btr(F)**-1com(E)
Bedroom	**B&Btr(F)-1com(E)**-1com(F)-2com(E or F)	**B&Btr(F)-1com(E)**-1com(F)-2com(E or F)
Kitchen (not to be covered)	1com(HtE)-**1com(E)**-2com(E)-1com(F)	1com(HtE)-**1com(E)**-2com(E)-1com(F)
Kitchen (to be covered)	B&Btr(F)-**1com(HtF)-1com(F)**-2com(F)	B&Btr(F)-**1com(HtF)-1com(F)**-2com(F)
Shelving	**1com**-2com	**1com**-2com
Stepping	**B&Btr(HtE)-B&Btr(E)-B&Btr(F)**-1com(E)	**B&Btr(HtE)-B&Btr(E)-B&Btr(F)**-1com(E)
Exterior uses:		
Window and door frames	**B&Btr-1com**-2com	**B&Btr-1com**-2com
Bungalow and colonial siding		
Bevel siding	**B&Btr**-1com-2com	**B&Btr**-1com-2com
Rustic and drop siding	**B&Btr**-1com-2com	**B&Btr**-1com-2com
Porch flooring (covered)	**1com(F)**-2com(F)	**1com(F)**-2com(F)
Porch flooring (uncovered)	**B&Btr(HtE)-B&Btr(HtF)**-1com(E)	**B&Btr(HtE)-B&Btr(HtF)**-1com(E)
Stepping	**B&Btr(HtE)-B&Btr(HtF)**-1com(E)	**B&Btr(HtE)-B&Btr(HtF)**-1com(E)
Exterior trim	**B&Btr**-1com-2com	**B&Btr**-1com-2com
Sheathing, etc.:		
Wall sheathing	1com-**2com**-3com	1com-**2com**-3com
Roof sheathing	1com-**2com**-3com	1com-**2com**-3com
Subflooring	1com-**2com**-3com	1com-**2com**-3com
Framing:		
Posts	StSqEdgSd-**1C**	StSqEdgSd--**1com**
Girders	StSqEdgSd-**1C**	StSqEdgSd--**1com**
Sills	Merch-**1C**	Merch-**1com**
Joists and rafters	StSqEdgSd-**1C**-2C	StSqEdgSd-**1C-2c**
Plates, headers, braces	1com-**2com**	1com-**2com**
Studs	1com-**2com**	1com-**2com**
Cross-bridging, ribbons, ties	1com-**2com**	1com-**2com**

Dwelling construction	North Carolina pine	Arkansas soft pine
	North Carolina Pine Association	Southern Pine Association
Interior uses:		
Finish and woodwork (natural finish)	**B&Btr**	**B&Btr**
Finish and woodwork (paint finish)	**1com**-2com	**1com**-2com
Moldings (natural and paint finish)	**B&Btr**	**B&Btr**
Flooring:		
Living and dining room, hall, etc	**B&Btr(HtE)-B&Btr(E)-B&Btr(F)**-1com(E)	**B&Btr(HtE)-B&Btr(E)-B&Btr(F)**-1com(E)
Bedroom	**B&Btr(F)-1com(E)**-1com(F)-2com(E or F)	**B&Btr(F)-1com(E)**-1com(F)-2com(E or F)
Kitchen (not to be covered)	1com(HtE)-**1com(E)**-2com(E)-1com(F)	1com(HtE)-**1com(E)**-2com(E)-1com(F)
Kitchen (to be covered)	B&Btr(F)-**1com(HtF)-1com(F)**-2com(F)	B&Btr(F)**1com(HtF)-1com(F)**-2com(F)
Shelving	**1com**-2com	**1com**-2com
Stepping	**B&Btr(HtE)-B&Btr(E)-B&Btr(F)**-1com(E)	**B&Btr(HtE)-B&Btr(E)-B&Btr(F)**-1com(E)
Exterior uses:		
Window and door frames	**B&Btr-1com**-2com	**B&Btr-1com**-2com
Bungalow and colonial siding		
Bevel siding	**B&Btr**-1com-2com	**B&Btr**-1com-2com
Rustic and drop siding	**B&Btr**-1com-2com	**B&Btr**-1com-2com
Porch flooring (covered)	**1com(F)**-2com(F)	**1com(F)**-2com(F)
Porch flooring (uncovered)	**B&Btr(HtE)-B&Btr(HtF)**-1com(E)	**B&Btr(HtE)-B&Btr(HtF)**-1com(E)
Stepping	**B&Btr(HtE)-B&Btr(HtF)**-1com(E)	**B&Btr(HtE)-B&Btr(HtF)**-1com(E)
Exterior trim	**B&Btr**-1com-2com	**B&Btr**-1com-2com
Sheathing, etc.:		
Wall sheathing	1com-**2com**-3com	1com-**2com**-3com
Roof sheathing	1com-**2com**-3com	1com-**2com**-3com
Subflooring	1com-**2com**-3com	1com-**2com**-3com
Framing:		
Posts	StSqEdgSd-**1C**	StSqEdgSd-**1C**
Girders	StSqEdgSd-**1C**	StSqEdgSd-**1C**
Sills	Merch-**1C**	Merch-**1C**
Joists and rafters	StSqEdgSd-**1C-2C**	StSqEdgSd-**1C**-2C
Plates, headers, braces	1com-**2com**	1com-**2com**
Studs	1com-**2com**	1com-**2com**
Cross-bridging, ribbons, ties	1com-**2com**	1com-**2com**

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Farm uses	Longleaf southern pine Southern Pine Association	Shortleaf southern pine Southern Pine Association	North Carolina pine North Carolina Pine Association	Arkansas soft pine Southern Pine Association
Barns and other large buildings:				
Framing:				
Posts	StSqEdgSd-**1C**	StSqEdgSd-**1C**	StSqEdgSd-**1C**	StSqEdgSd-**1C**
Girders	StSqEdgSd-**1C**	StSqEdgSd-**1C**	StSqEdgSd-**1C**	StSqEdgSd-**1C**
Sills	Merch-**1C**	Merch-**1C**	Merch-**1C**	Merch-**1C**
Joists, rafters, trusses, plates and headers, braces, collar beams	StSqEdgSd-**1C**-2C	StSqEdgSd-**1C**-2C	StSqEdgSd-**1C**-2C	StSqEdgSd-**1C**-2C
Studs	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Cross-bridging, ribbons	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Drop siding, barn boards, and battens	B&Btr-**1com**-2com	B&Btr-**1com**-2com	B&Btr-**1com**-2com	B&Btr-**1com**-2com
Exterior trim and doors	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing, roof and wall	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Heavy flooring	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Subflooring	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Grooved roofing	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Stanchions and stalls	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Mangers	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Small farm structures (separate and lean-to sheds, stock shelters, hog, poultry, and dairy houses, small granaries):				
Framing:				
Posts, girders, sills, joists, rafters	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Studs, plates, headers, braces, collar ties, cross-bridging, ribbons	**2com**-3com	**2com**-3com	**2com**-3com	**2com**-3com
Siding, barn boards, exterior trim	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Flooring	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing (covered)	**2com**-3com	**2com**-3com	**2com**-3com	**2com**-3com
Inside equipment (roosts, nests, racks, shelving)	**2com**-3com	**2com**-3com	**2com**-3com	**2com**-3com
Corn cribbing	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Gates and fencing	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
General uses related to building construction				
Scaffolding	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Staging	**1com**	**1com**	**1com**	**1com**
Concrete forms:				
Boards	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Dimension	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Longleaf southern pine Southern Pine Association
Bridge and construction timber		
Combination and Howe truss spans		
Compression members	Posts and timbers	DseHt-StrSqEdgSd-No1com
Tension	Joist and plank	DseHt-StSqEdgSd-No1com
Diagonals subject to reverse stress	Posts and timbers	DseHt-StSqEdgSd-No1com
Floor beams and stringers	Beams and stringers	SelStr(Dse)-DseHt-StrSqEdgeSd-No1com
Ties	Timbers	DseHt-StSqEdgeSd-No1com
Guard timbers	Timbers	StSqEdgSd-**No1com**
Railing	Dimension	**1com**
Stiffeners	Dimension	**1com**
Splices	Dimension	**1com**
Nailing strips	Dimension	**1com**
Grillage	Timbers	StSqEdgSd-**No1com**
Deck plank	Dimension	**1com**
Bridging	Boards	1com-**2com**
Pile and frame trestles:		
Sills and mud sills	Timbers	DseHt-StSqEdgSd-No1com
Posts	Posts	DseHt-StSqEdgSd-No1com
Caps	Timbers	DseHt-StSqEdgSd-No1com
Sash bracing	Plank	StSqEdgSd-**No1com**
Cross-bracing	Plank	StSqEdgSd-**No1com**
Longitudinal bracing	Plank	StSqEdgSd-**No1com**
Girts	Timbers	StSqEdgSd-**No1com**
End planks	Planks	StSqEdgSd-**No1com**
Stringers	Stringers	SelStr(Dse)-DseHt-StSqEdgSd-No1com
Ties	Timbers	DseHt-StSqEdgSd-No1com
Guard timbers	Timbers	StSqEdgSd-**No1com**
Planking for ballasted deck	Plank	DseHt-StSqEdgSd-No1com
Railing	Dimension	**1com**
False work:		
Sills and mud sills	Timbers	Merch-**No1com**
Posts	Posts	StSqEdgSd-**No1com**
Caps	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-StSqEdgSd-No1com
Truss timbers	Timbers	StSqEdgSd-**No1com**
Centering	Dimension	**1com**
Lagging	Dimension	**1com**
Bracing	Plank	StSqEdgSd-**No1com**
Wedges	Dimension	**1com**
Scaffolding	Dimension	1com-**2com**
Concrete forms:		
Dimension lumber	Dimension	**1com**-2com
D & M planks	.....	1com-**2com**
Bracing	Boards	1com-**2com**
Tanks and supports:		
Sills	Timbers	Merch-**No1com**
Posts	Posts	DseHt-StSqEdgSd-No1com
Caps	Timbers	DseHt-StSqEdgSd-No1com
Bracing	Plank	StSqEdgSd-**No1com**
Joists	Joist	DseHt-StSqEdgSd-No1com
D & M flooring	Heavy flooring	**C**
*Staves	.....	***Tank Stock**
Rafters	Dimension	**1com**-2com
Roof	Shiplap	**1com**-2com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Longleaf southern pine Southern Pine Association
Tanks and supports continued		
Ladders, etc		**C**-1com
Frost box material	Shiplap	**1com**-2com
Docks and wharves:		
Timber sheet piling	Timbers	StSqEdgSd-**No1com**
Timber in cribs	Timbers	StSqEdgSd-**No1com**
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Stringers	Stringers	SelStr(Dse)-**DseHt-StSqEdgSd**-No1com
Bracing	Plank	StSqEdgSd-**No1com**
Guard timber	Timbers	StSqEdgSd-**No1com**
Ties	Timbers	DseHt-**StSqEdgSd**-No1com
Plank decking	Plank	DseHt-**StSqEdgSd**-No1com
Mooring posts	Timbers	DseHt-**StSqEdgSd**-No1com
Fenders and wales	Timbers	StSqEdgSd-**No1com**
Coaling and ore stations:		
Sills and mud sills	Timbers	StSqEdgSd-**No1com**
Posts	Posts	DseHt-**StSqEdgSd**-No1com
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Bracing	Plank	StSqEdgSd-**No1com**
Stringers	Stringers	SelSt-**DseHt-StSqEdgSd**-No1com
Joists	Joists	DseHt-**StSqEdgSd**-No1com
Bin lining	Dimension	**1com**-2com
Rafters	Dimension	**1com**-2com
Flooring	Boards	**1com**-2com
Chutes	Boards	**1com**-2com
Decking	Boards	**1com**-2com
Coal pockets and bins	Dimension	**1com**-2com
Roofing	Shiplap	1com-**2com**
Tunnels:		
Posts	Posts	DseHt-**StSqEdgSd**-No1com
Sills	Timbers	DseHt-**StSqEdgSd**-No1com
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Segments	Timbers	DseHt-**StSqEdgSd**-No1com
Lagging	Dimension	**1com**-2com
Struts	Dimension	**1com**-2com
Caisson	Timbers	DseHt-**StSqEdgSd**-No1com

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the left, and alternate grades of lower quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the associations publishing rules covering the various species are shown in the column heading.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Shortleaf southern pine Southern Pine Association
Bridge and construction timber:		
Combination and Howe truss spans		
Compression members	Posts and timbers	DseHt-**StrSqEdgSd**-No1com
Tension	Joist and plank	DseHt-**StrSqEdgSd**-No1com
Diagonals subject to reverse stress	Posts and timbers	DseHt-**StrSqEdgSd**-No1com
Floor beams and stringers	Beams and stringers	SelStr(Dse)-**DseHt-StrSqEdgSd**-No1com
Ties	Timbers	DseHt-**StSqEdgSd**-No1com
Guard timbers	Timbers	StSqEdgSd-**No1com**
Railing	Dimension	**1com**
Stiffeners	Dimension	**1com**
Splices	Dimension	**1com**
Nailing strips	Dimension	**1com**
Grillage	Timbers	StSqEdgSd-**No1com**
Deck plank	Dimension	**1com**
Bridging	Boards	1com-**2com**
Pile and frame trestles:		
Sills and mud sills	Timbers	DseHt-**StSqEdgSd**-No1com
Posts	Posts	DseHt-**StSqEdgSd**-No1com
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Sash bracing	Plank	StSqEdgSd-**No1com**
Cross-bracing	Plank	StSqEdgSd-**No1com**
Longitudinal bracing	Plank	StSqEdgSd-**No1com**
Girts	Timbers	StSqEdgSd-**No1com**
End planks	Planks	StSqEdgSd-**No1com**
Stringers	Stringers	SelStr(Dse)-**DseHt-StSqEdgSd**-No1com
Ties	Timbers	DseHt-**StSqEdgSd**-No1com
Guard timbers	Timbers	StSqEdgSd-**No1com**
Planking for ballasted deck	Plank	DseHt-**StSqEdgSd**-No1com
Railing	Dimension	**1com**
False work:		
Sills and mud sills	Timbers	Merch-**No1com**
Posts	Posts	StSqEdgSd-**No1com**
Caps	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-**StSqEdgSd**-No1com
Truss timbers	Timbers	StSqEdgSd-**No1com**
Centering	Dimension	**1com**
Lagging	Dimension	**1com**
Bracing	Plank	StSqEdgSd-**No1com**
Wedges	Dimension	**1com**
Scaffolding	Dimension	1com-**2com**
Concrete forms:		
Dimension lumber	Dimension	**1com**-2com
D & M planks	.....	1com-**2com**
Bracing	Boards	1com-**2com**
Tanks and supports:		
Sills	Timbers	StSqEdgSd-**No1com**
Posts	Posts	DseHt-**StSqEdgSd**-No1com
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Bracing	Plank	StSqEdgSd-**No1com**
Joists	Joist	DseHt-**StSqEdgSd**-No1com
D & M flooring	Heavy flooring	C
*Staves	.....	*Tank Stock
Rafters	Dimension	**1com**-2com
Roof	Shiplap	**1com**-2com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Shortleaf southern pine
		Southern Pine Association
Tanks and supports, continued:		
Ladders, etc.		C-1com
Frost box material	Ship lap	**1com**-2com
Docks and wharves:		
Timber sheet piling	Timbers	StSqEdgSd-**No1com**
Timber in cribs	Timbers	StSqEdgSd-**No1com**
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Stringers	Stringers	SelStr(Dse)-**DseHt-StSqEdgSd**-No1com
Bracing	Plank	StSqEdgSd-**No1com**
Guard timber	Timbers	StSqEdgSd-**No1com**
Ties	Timbers	DseHt-**StSqEdgSd**-No1com
Plank decking	Plank	DseHt-**StSqEdgSd**-No1com
Mooring posts	Timbers	DseHt-**StSqEdgSd**-No1com
Fenders and wales	Timbers	StSqEdgSd-**No1com**
Coaling and ore stations:		
Sills and mud sills	Timbers	Merch-**No1com**
Posts	Posts	DseHt-**StSqEdgSd**-No1com
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Bracing	Plank	StSqEdgSd-**No1com**
Stringers	Stringers	SelSt-**DseHt-StSqEdgSd**-No1com
Joists	Joists	DseHt-**StSqEdgSd**-No1com
Bin lining	Dimension	**1com**-2com
Rafters	Dimension	**1com**-2com
Flooring	Boards	**1com**-2com
Chutes	Boards	**1com**-2com
Decking	Boards	**1com**-2com
Coal pockets and bins	Dimension	**1com**-2com
Roofing	Shiplap	1com-**2com**
Tunnels:		
Posts	Posts	DseHt-**StSqEdgSd**-No1com
Sills	Timbers	DseHt-**StSqEdgSd**-No1com
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Segments	Timbers	DseHt-**StSqEdgSd**-No1com
Lagging	Dimension	**1com**-2com
Struts	Dimension	**1com**-2com
Caisson	Timbers	DseHt-**StSqEdgSd**-No1com

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	North Carolina pine North Carolina Pine Association
Bridge and construction timber:		
Combination and Howe truss spans		
Compression members	Posts and timbers	DseHt-**StrSqEdgSd**-No1com
Tension	Joist and plank	DseHt-**StrSqEdgSd**-No1com
Diagonals subject to reverse stress	Posts and timbers	DseHt-**StrSqEdgSd**-No1com
Floor beams and stringers	Beams and stringers	SelStr(Dse)-**DseHt-StrSqEdgSd**-No1com
Ties	Timbers	DseHt-**StSqEdgSd**-No1com
Guard timbers	Timbers	StSqEdgSd-**No1com**
Railing	Dimension	**1com**
Stiffeners	Dimension	**1com**
Splices	Dimension	**1com**
Nailing strips	Dimension	**1com**
Grillage	Timbers	StSqEdgSd-**No1com**
Deck plank	Dimension	**1com**
Bridging	Boards	1com-**2com**
Pile and frame trestles:		
Sills and mud sills	Timbers	DseHt-**StSqEdgSd**-No1com
Posts	Posts	DseHt-**StSqEdgSd**-No1com
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Sash bracing	Plank	StSqEdgSd-**No1com**
Cross-bracing	Plank	StSqEdgSd-**No1com**
Longitudinal bracing	Plank	StSqEdgSd-**No1com**
Girts	Timbers	StSqEdgSd-**No1com**
End planks	Planks	StSqEdgSd-**No1com**
Stringers	Stringers	SelStr(Dse)-**DseHt-StSqEdgSd**-No1com
Ties	Timbers	DseHt-**StSqEdgSd**-No1com
Guard timbers	Timbers	StSqEdgSd-**No1com**
Planking for ballasted deck	Plank	DseHt-**StSqEdgSd**-No1com
Railing	Dimension	**1com**
False work:		
Sills and mud sills	Timbers	Merch-**No1com**
Posts	Posts	StSqEdgSd-**No1com**
Caps	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-**StSqEdgSd**-No1com
Truss timbers	Timbers	StSqEdgSd-**No1com**
Centering	Dimension	**1com**
Lagging	Dimension	**1com**
Bracing	Plank	StSqEdgSd-**No1com**
Wedges	Dimension	**1com**
Scaffolding	Dimension	1com-**2com**
Concrete forms:		
Dimension lumber	Dimension	**1com**-2com
D & M planks	.....	1com-**2com**
Bracing	Boards	1com-**2com**
Tanks and supports:		
Sills	Timbers	StSqEdgSd-**No1com**
Posts	Posts	DseHt-**StSqEdgSd**-No1com
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Bracing	Plank	StSqEdgSd-**No1com**
Joists	Joist	DseHt-**StSqEdgSd**-No1com
D & M flooring	Heavy flooring	**C**
*Staves	.....	***Tank Stock**
Rafters	Dimension	**1com**-2com
Roof	Shiplap	**1com**-2com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	North Carolina pine
		North Carolina Pine Association
Tanks and supports, continued:		
Ladders, etc.	.....	**C**-1com
Frost box material	Shiplap	**1com**-2com
Docks and wharves:		
Timber sheet piling	Timbers	StSqEdgSd-**No1com**
Timber in cribs	Timbers	StSqEdgSd-**No1com**
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Stringers	Stringers	SelStr(Dse)-**DseHt-StSqEdg d**-No1com
Bracing	Plank	StSqEdgSd-**No1com**
Guard timber	Timbers	StSqEdgSd-**No1com**
Ties	Timbers	DseHt-**StSqEdgSd**-No1com
Plank decking	Plank	DseHt-**StSqEdgSd**-No1com
Mooring posts	Timbers	DseHt-**StSqEdgSd**-No1com
Fenders and wales	Timbers	StSqEdgSd-**No1com**
Coaling and ore stations:		
Sills and mud sills	Timbers	Merch-**No1com**
Posts	Posts	DseHt-**StSqEdgSd**-No1com
Caps	Timbers	DseHt-**StSqEdgSd**-No1com
Bracing	Plank	StSqEdgSd-**No1com**
Stringers	Stringers	SelSt-**DseHt-StSqEdgSd**-No1com
Joists	Joists	DseHt-**StSqEdgSd**-No1com
Bin lining	Dimension	**1com**-2com
Rafters	Dimension	**1com**-2com
Flooring	Boards	**1com**-2com
Chutes	Boards	**1com**-2com
Decking	Boards	**1com**-2com
Coal pockets and bins	Dimension	**1com**-2com
Roofing	Shiplap	1com-**2com**
Tunnels:		
Posts	Posts	DseHt-**StSqEdgSd**-No1com
Sills	Timbers	DseHt-StSqEdgSd-No1com
Caps	Timbers	DseHt-StSqEdgSd-No1com
Segments	Timbers	DseHt-StSqEdgSd-No1com
Lagging	Dimension	**1com**-2com
Struts	Dimension	**1com**-2com
Caisson	Timbers	DseHt-StSqEdgSd-No1com

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Longleaf southern pine Southern Pine Association
Station buildings, passenger, freight, platform shelters:		
Caps	Timbers	StSqEdgSd-**No1com**
Sills	Timbers	Merch-**No1com**
Posts	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-StSqEdgSd-No1com
Joists	Joists	StSqEdgSd-**No1com**
Bridging	Boards	2com-**3com**
Subflooring	Shiplap	1com-**2com**-3com
Finish flooring (natural finish)	Flooring	B&Btr(HtE)-**B&Btr(E)-B&Btr(F)**-1com(E)
Finish flooring (paint finish)	Flooring	B&Btr(F)-**1com(E)-1com(F)**
Studding and plates	Dimension	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com
Siding	Siding	**B&Btr**-1com
Ceiling (natural finish)	Ceiling	**B&Btr**
Ceiling (paint finish)	Ceiling	***1com**
Truss timbers	Dimension	**1com**-2com
Purlins	Dimension	**1com**-2com
Rafters	Dimension	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com
Shingles (roof)	Shingles	***Select**
Shingles (sidewalls)	Shingles	*Select-**No1**
Door and window frames	Finish lumber	B&Btr-C-1com
Outside finish lumber	Finish lumber	B&Btr-**C**-1com
Inside finish (natural)	Finish lumber	**B&Btr**
Inside finish (paint)	Finish lumber	C-1com
Millwork (moldings)	Molding	**B&Btr**
Millwork (stairs)	Finish lumber	**B&Btr-C**
Partitions	Partition	**B&Btr**-1com
Shelving	Finish lumber	B&Btr-C
Engine houses and machine shops:		
Caps	Timbers	StSqEdgSd-**No1com**
Sills	Timbers	Merch-**No1com**
Posts	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-StSqEdgSd-No1com
Joists	Joists	DseHt-StSqEdgSd-No1com
Bridging	Boards	2com-**3com**
Flooring	Dimension	**1com**
Pit timbers	Timbers	StSqEdgSd-**No1com**
Studding	Dimension	**1com**-2com
Furring	Strips	1com-**2com**-3com
Siding	Siding	***B&Btr**-1com
Ceiling	Ceiling	***B**-1com
Truss timber	Dimension	**1com**-2com
Purlins	Dimension	**1com**-2com
Rafters	Dimension	**1com**-2com
Roofboards	Shiplap	1com-**2com**-3com
Shingles	Shingles	***Select**
Door and window frames	Finish lumber	B&Btr-**C**-1com
Outside finish lumber	Finish lumber	B&Btr-C-1com
Inside finish lumber	Finish lumber	B&Btr-C-1com
Millwork	Finish lumber	B&Btr-C-1com
Sleepers	Dimension	1com-**2com**
Section houses and small buildings:		
Posts	Dimension	1com-**2com**
Sills	Dimension	1com-**2com**
Caps	Dimension	1com-**2com**
Joists (section houses)	Dimension	**1com**
Joists (small bldgs.)	Joist	StSqEdgSd-**No1com**
Bridging	Boards	2com-**3com**
Subflooring	Shiplap	1com-**2com**-3com
Finish flooring (natural finish)	Flooring	B&Btr(HtE)-**B&Btr(E)-B&Btr(F)**-1com(E)
Finish flooring (paint finish)	Flooring	B&Btr(F)-**1com(E)-1com(F)**
Studding and plates	Dimension	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com
Siding	Siding	***B&Btr**-1com
Ceiling	Ceiling	***B**-1com
Rafters	Dimension	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com
Shingles	Shingles	***Select**
Door and window frames	Finish lumber	B&Btr-C-1com
Outside finish lumber	Finish lumber	B&Btr-C-1com
Inside finish lumber	Finish lumber	B&Btr-C-1com
Millwork	Finish lumber	B&Btr-**C**-1com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Longleaf southern pine
		Southern Pine Association
Warehouses and ice houses:		
Caps	Timbers	StSqEdgSd-**No1com**
Sills	Timbers	Merch-**No1com**
Posts	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-StSqEdgSd-No1com
Joists (warehouses)	Joists	DseHt-StSqEdgSd-No1com
Joists (ice houses)	Dimension	**1com**
Bridging	Boards	1com-**2com**-3com
Subflooring	Boards	1com-**2com**-3com
Finish flooring	Flooring	B&Btr(F)-**1com(E)-1com(F)**
Studding and plates	Dimension	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com
Siding	Siding	***B&Btr**-1com
Ceiling	Ceiling	***B**-1com
Truss timbers	Dimension	**1com**-2com
Purlins	Dimension	**1com**-2com
Rafters	Rafters	**1com**-2com
Roofboards	Shiplap	1com-**2com**-3com
Shingles	Shingles	*Select
Door and window frames	Finish lumber	B&Btr-**C**-1com
Outside finish lumber	Finish lumber	B&Btr-**C**-1com
Inside finish lumber	Finish lumber	B&Btr-**C**-1com
Millwork	Finish lumber	B&Btr-**C**-1com
Sleepers	Strips	1com-**2com**-3com

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Shortleaf southern pine Southern Pine Association
tation buildings, passenger, freight, platform shelters:		
Caps	Timbers	StSqEdgSd-**No1com**
Sills	Timbers	Merch-**No1com**
Posts	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-StSqEdgSd-No1com
Joists	Joists	StSqEdgSd-**No1com**
Bridging	Boards	2com-**3com**
Subflooring	Shiplap	1com-**2com**-3com
Finish flooring (natural finish)	Flooring	B&Btr(HtE)-**B&Btr(E)**-**B&Btr(F)**-1com(E)
Finish flooring (paint finish)	Flooring	B&Btr(F)-**1com(E)**-**1com(F)**
Studding and plates	Dimension	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com
Siding	Siding	**B&Btr**-1com
Ceiling (natural finish)	Ceiling	**B&Btr**
Ceiling (paint finish)	Ceiling	***1com**
Truss timbers	Dimension	**1com**-2com
Purlins	Dimension	**1com**-2com
Rafters	Dimension	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com
Shingles (roof)	Shingles	***Select**
Shingles (sidewalls)	Shingles	*Select-**No1**
Door and window frames	Finish lumber	B&Btr-C-1com
Outside finish lumber	Finish lumber	B&Btr-C-1com
Inside finish (natural)	Finish lumber	**B&Btr**
Inside finish (paint)	Finish lumber	**C**-1com
Millwork (moldings)	Molding	**B&Btr**
Millwork (stairs)	Finish lumber	**B&Btr-C**
Partitions	Partition	**B&Btr**-1com
Shelving	Finish lumber	**B&Btr-C**
ngine houses and machine shops:		
Caps	Timbers	StSqEdgSd-**No1com**
Sills	Timbers	Merch-**No1com**
Posts	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-StSqEdgSd-No1com
Joists	Joists	DseHt-StSqEdgSd-No1com
Bridging	Boards	2com-**3com**
Flooring	Dimension	**1com**
Pit timbers	Timbers	StSqEdgSd-**No1com**
Studding	Dimension	**1com**-2com
Furring	Strips	1com-**2com**-3com
Siding	Siding	***B&Btr**-1com
Ceiling	Ceiling	***B**-1com
Truss timber	Dimension	**1com**-2com
Purlins	Dimension	**1com**-2com
Rafters	Dimension	**1com**-2com
Roofboards	Shiplap	1com-**2com**-3com
Shingles	Shingles	***Select**
Door and window frames	Finish lumber	B&Btr-C-1com
Outside finish lumber	Finish lumber	B&Btr-C-1com
Inside finish lumber	Finish lumber	B&Btr-C-1com
Millwork	Finish lumber	B&Btr-C-1com
Sleepers	Dimension	1com-**2com**
ction houses and small buildings:		
Posts	Dimension	1com-**2com**
Sills	Dimension	1com-**2com**
Caps	Dimension	1com-**2com**
Joists (section houses)	Dimension	**1com**
Joists (small bldgs.)	Joist	StSqEdgSd-**No1com**
Bridging	Boards	2com-**3com**
Subflooring	Shiplap	1com-**2com**-3com
Finish flooring (natural finish)	Flooring	B&Btr(HtE)-**B&Btr(E)**-**B&Btr(F)**-1com(E)
Finish flooring (paint finish)	Flooring	B&Btr(F)-**1com(E)**-**1com(F)**
Studding and plates	Dimension	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com
Siding	Siding	***B&Btr**-1com
Ceiling	Ceiling	***B**-1com
Rafters	Dimension	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com
Shingles	Shingles	***Select**
Door and window frames	Finish lumber	B&Btr-C-1com
Outside finish lumber	Finish lumber	B&Btr-C-1com
Inside finish lumber	Finish lumber	B&Btr-C-1com
Millwork	Finish lumber	B&Btr-C-1com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Shortleaf southern pine
		Southern Pine Association
Warehouses and ice houses:		
Caps	Timbers	StSqEdgSd-**No1com**
Sills	Timbers	Merch-**No1com**
Posts	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-StSqEdgSd-No1com
Joists (warehouses)	Joists	DseHt-StSqEdgSd-No1com
Joists (ice houses)	Dimension	**1com**
Bridging	Boards	1com-**2com**-3com
Subflooring	Boards	1com-**2com**-3com
Finish flooring	Flooring	B&Btr(F)-**1com(E)-1com(F)**
Studding and plates	Dimension	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com
Siding	Siding	***B&Btr**-1com
Ceiling	Ceiling	***B**-1com
Truss timbers	Dimension	**1com**-2com
Purlins	Dimension	**1com**-2com
Rafters	Rafters	**1com**-2com
Roofboards	Shiplap	1com-**2com**-3com
Shingles	Shingles	***Select**
Door and window frames	Finish lumber	B&Btr-**C**-1com
Outside finish lumber	Finish lumber	B&Btr-**C**-1com
Inside finish lumber	Finish lumber	B&Btr-**C**-1com
Millwork	Finish lumber	B&Btr-**C**-1com
Sleepers	Strips	1com-**2com**-3com

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	North Carolina pine North Carolina Pine Association
Station buildings, passenger, freight, platform shelters:		
Caps	Timbers	StSqEdgSd-**No1com**
Sills	Timbers	Merch-**No1com**
Posts	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-StSqEdgSd-No1com
Joists	Joists	StSqEdgSd-**No1com**
Bridging	Boards	2com-**3com**
Subflooring	Shiplap	1com-**2com**-3com
Finish flooring (natural finish)	Flooring	B&Btr(HtE)-B&Btr(E)-B&Btr(F)-1com(E)
Finish flooring (paint finish)	Flooring	B&Btr(F)-**1com**(E)-**1com**(F)
Studding and plates	Dimension	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com
Siding	Siding	**B&Btr**-1com
Ceiling (natural finish)	Ceiling	**B&Btr**
Ceiling (paint finish)	Ceiling	***1com**
Truss timbers	Dimension	**1com**-2com
Purlins	Dimension	**1com**-2com
Rafters	Dimension	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com
Shingles (roof)	Shingles	***Select**
Shingles (sidewalls)	Shingles	*Select-**No1**
Door and window frames	Finish lumber	B&Btr-C-1com
Outside finish lumber	Finish lumber	B&Btr-C-1com
Inside finish (natural)	Finish lumber	**B&Btr**
Inside finish (paint)	Finish lumber	C-1com
Millwork (moldings)	Molding	**B&Btr**
Millwork (stairs)	Finish lumber	**B&Btr-C**
Partitions	Partition	**B&Btr**-1com
Shelving	Finish lumber	B&Btr-**C**
Engine houses and machine shops:		
Caps	Timbers	StSqEdgSd-**No1com**
Sills	Timbers	Merch-**No1com**
Posts	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-StSqEdgSd-No1com
Joists	Joists	DseHt-StSqEdgSd-No1com
Bridging	Boards	2com-**3com**
Flooring	Dimension	**1com**
Pit timbers	Timbers	StSqEdgSd-**No1com**
Studding	Dimension	**1com**-2com
Furring	Strips	1com-**2com**-3com
Siding	Siding	***B&Btr**-1com
Ceiling	Ceiling	***B**-1com
Truss timber	Dimension	**1com**-2com
Purlins	Dimension	**1com**-2com
Rafters	Dimension	**1com**-2com
Roofboards	Shiplap	1com-**2com**-3com
Shingles	Shingles	***Select**
Door and window frames	Finish lumber	B&Btr-C-1com
Outside finish lumber	Finish lumber	B&Btr-C-1com
Inside finish lumber	Finish lumber	B&Btr-C-1com
Millwork	Finish lumber	B&Btr-C-1com
Sleepers	Dimension	1com-**2com**
Section houses and small buildings:		
Posts	Dimension	1com-**2com**
Sills	Dimension	1com-**2com**
Caps	Dimension	1com-**2com**
Joists (section houses)	Dimension	**1com**
Joists (small bldgs.)	Joist	StSqEdgSd-**No1com**
Bridging	Boards	2com-**3com**
Subflooring	Shiplap	1com-**2com**-3com
Finish flooring (natural finish)	Flooring	B&Btr(HtE)-B&Btr(E)-B&Btr(F)-1com(E)
Finish flooring (paint finish)	Flooring	B&Btr(F)-**1com**(E)-**1com**(F)
Studding and plates	Dimension	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com
Siding	Siding	***B&Btr**-1com
Ceiling	Ceiling	***B**-1com
Rafters	Dimension	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com
Shingles	Shingles	***Select**
Door and window frames	Finish lumber	B&Btr-C-1com
Outside finish lumber	Finish lumber	B&Btr-C-1com
Inside finish lumber	Finish lumber	B&Btr-C-1com
Millwork	Finish lumber	B&Btr-C-1com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	North Carolina pine
		North Carolina Pine Association
Warehouses and ice houses:		
Caps	Timbers	StSqEdgSd-**No1com**
Sills	Timbers	Merch-**No1com**
Posts	Timbers	StSqEdgSd-**No1com**
Stringers	Stringers	DseHt-StSqEdgSd-No1com
Joists (warehouses)	Joists	DseHt-StSqEdgSd-No1com
Joists (ice houses)	Dimension	**1com**
Bridging	Boards	1com-**2com**-3com
Subflooring	Boards	1com-**2com**-3com
Finish flooring	Flooring	B&Btr(F)-**1com(E)**-**1com(F)**
Studding and plates	Dimension	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com
Siding	Siding	***B&Btr**-1com
Ceiling	Ceiling	***B**-1com
Truss timbers	Dimension	**1com**-2com
Purlins	Dimension	**1com**-2com
Rafters	Rafters	**1com**-2com
Roofboards	Shiplap	1com-**2com**-3com
Shingles	Shingles	***Select**
Door and window frames	Finish lumber	B&Btr-**C**-1com
Outside finish lumber	Finish lumber	B&Btr-**C**-1com
Inside finish lumber	Finish lumber	B&Btr-**C**-1com
Millwork	Finish lumber	B&Btr-**C**-1com
Sleepers	Strips	1com-**2com**-3com

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the left, and alternate grades of lower quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the associations publishing rules covering the various species are shown in the column heading.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Longleaf southern pine Southern Pine Association	Shortleaf southern pine Southern Pine Association	North Carolina pine North Carolina Pine Association
Miscellaneous roadway material:				
Crossing plank	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Platforms:				
Posts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Caps	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sills	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Stringers	Stringers	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com
Joists	Joists	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com
Bridging	Boards	2com-**3com**	2com-**3com**	2com-**3com**
Planking	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Railing	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Steps	Boards	**1com**-2com	**1com**-2com	**1com**-2com
Skids	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Stock Guards:				
Posts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Ties	Timbers	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Longleaf southern pine	Shortleaf southern pine	North Carolina pine
		Southern Pine Association	Southern Pine Association	North Carolina Pine Association
Stock Guards, continued:				
Wing fences and aprons	Boards	1com-2com	1com-2com	1com-2com
Slats	Boards	1com-2com	1com-2com	1com-2com
Fillers	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Signs and Posts:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Bracing	Dimension	1com-2com-3com	1com-2com-3com	1com-2com-3com
Sign Boards	Finish lumber	B&Btr-C-1com	B&Btr-C-1com	B&Btr-C-1 com
Molding	Molding	*B&Btr	*B&Btr	*B&Btr
Fencing, including snow fence:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Bracing	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Stringers	Dimension	1com-2com	1com-2com	1com-2com
Fence boards	Boards	1com-2com	1com-2com	1com-2com
Gate materials	Boards	1com-2com	1com-2com	1com-2com
Stakes	Boards	1com-2com	1com-2com	1com-2com
Culverts and drains:				
Sills	Timbers	Merch-No1com	Merch-No1com	Merch-No1com
Bracing	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com

Culverts and drains, continued:				
Timbers	Timbers	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**
Planking	Dimension	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Grillage	Timbers	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**
Stock pens:				
Posts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sills	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Fencing	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Studding	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Shingles	Shingles	**Select**-No1	**Select**-No1	
Outside finish lumber	Finish lumber	B&Btr-**C**-1com	B&Btr-**C**-1com	B&Btr-**C**-1com
Poles	Timbers	DseHt-**StSqEdgSd**-No1com	DseHt-**StSqEdgSd**-No1com	DseHt-**StSqEdgSd**-No1com
Conduits	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Bumping blocks	Timbers	DseHt-**StSqEdgSd**-No1com	DseHt-**StSqEdgSd**-No1com	DseHt-**StSqEdgSd**-No1com
Railroad Cars[1]				
Battens, door	Strips	**1com**-2com	**1com**-2com	**1com**-2com
Beams, needle	Timbers	**DseHt**-StSqEdgSd	**DseHt**-StSqEdgSd	**DseHt**-StSqEdgSd
Belt rail	Boards	**1com**-2com	**1com**-2com	**1com**-2com
Boards, card, legend, number	Finish lumber	B&Btr-**C**	B&Btr-**C**	B&Btr-**C**
Braces	Joists	**DseHt-StSqEdgSd**	DseHt-**StSqEdgSd**	DseHt-**StSqEdgSd**
Carlines	Dimension	**1com**	**1com**	**1com**
Decking or flooring	Heavy flooring or decking			

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Longleaf southern pine	Shortleaf southern pine	North Carolina pine
		Southern Pine Association	Southern Pine Association	North Carolina Pine Association
Railroad cars, continued:				
Open cars		B&Btr-C-1com	B&Btr-C-1com	B&Btr-C-1com
Box cars		B&Btr-C-1com	B&Btr-C-1com	B&Btr-C-1com
Stock cars		B&Btr-C-1com	B&Btr-C-1com	B&Btr-C-1com
Subflooring		1com	1com	1com
Door header	Dimension	1com	1com	1com
Door, grain	Boards	1com	1com	1com
Door, side	Siding	B&Btr-1com	B&Btr-1com	B&Btr-1com
Fascia	Finish lumber	B&Btr	B&Btr	B&Btr
Framing, car	Joists	DseHt-StSqEdgSd	DseHt-StSqEdgSd	DseHt-StSqEdgSd
Framing, box car side door	Joists	StSqEdgSd-No1com	StSqEdgSd-No1com	StSqEdgSd-No1com
Lining	Lining			
Refrigerator and box car without siding		B&Btr	B&Btr	B&Btr
Refrigerator and box car with siding		1com	1com	1com
Plank, side and end	Plank	1com	1com	1com
Posts, corner	Joist	StSqEdgSd-1com	StSqEdgSd-1com	StSqEdgSd-1com

Railroad cars, continued:				
Posts, door	Joist	**StSqEdgSd-1com**	**StSqEdgSd-1com**	**StSqEdgSd-1com**
Roofing	Roofing			
Single board and outside double board	.....	**B&Btr-1com**	**B&Btr-1com**	**B&Btr-1com**
Double board inside	.....	**1com**	**1com**	**1com**
Running boards	Finish lumber	**B&Btr**	**B&Btr**	**B&Btr**
Ridge pole	Dimension	**1com**	**1com**	**1com**
Siding or sheathing	Siding	**B&Btr-1com**	**B&Btr-1com**	**B&Btr-1com**
Sills	Stringers	**DseHt-StSqEdgSd**	DseHt-StSqEdgSd	DseHt-StSqEdgSd
Stakes	Dimension	**1com**	**1com**	**1com**

[1] First grade recommended is for new cars; second, for repairs.

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee of VII the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the left, and alternate grades of lower quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the associations publishing rules covering the various species are shown in the column headings.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Industrial buildings	Item	Longleaf southern pine	Shortleaf southern pine	North Carolina pine
		Southern Pine Association	Southern Pine Association	North Carolina Pine Association
Posts	Timbers	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**
Caps	Timbers	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**
Girders	Beams	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com
Stringers	Stringers	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com
Heavy joists	Joists	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com
Heavy flooring	Heavy flooring	**1com**-Block	**1com**-Block	**1com**-Block
Plates	Joists	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**
Truss members	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roof planking	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Bridging	Boards	**2com**-3com	**2com**-3com	**2com**-3com
Sills	Timbers	Merch-**No1com**	Merch-**No1com**	Merch-**No1com**
Airplane hangars				
Framing:				
Sills	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Studs	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Plates	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Truss members	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Siding	Siding	**B&Btr**-1com	B&Btr-1com	**B&Btr**-1com
Sheathing, wall and roof	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Trim, exterior and interior, window and door frames	Finish lumber	B&Btr-**C**-1com	B&Btr-C-1com	B&Btr-**C**-1com
Highway uses				
Bridges:				
Posts or columns	Posts	**StSqEgdSd**-No1com	**StSqEdSgd**-No1com	**StSqEdgSd**-No1com
Mud sills	Timbers	**Merch**-No1com	**Merch**-No1com	**Merch**-No1com
Sills	Timbers	**Merch**-No1com	**Merch**-No1com	**Merch**-No1com
Caps	Timbers	StSqEdgSd-No1com	StSqEdgSd-No1com	StSqEdgSd-No1com
Bracing	Joists	StSqEdgSd-No1com	StSqEdgSd-No1com	StSqEdgSd-No1com
Truss members	Joists	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com
Stringers	Stringers	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com
Floor beams	Stringers	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com	DseHt-StSqEdgSd-No1com

Bridging	Dimension	**1com-2com**	**1com-2com**	**1com-2com**
Nailing strips	Dimension	**1com-2com**	**1com-2com**	**1com-2com**
Flooring	Plank	DseHt-**StSqEdgSd-No1com**	DseHt-**StSqEdgSd-No1com**	DseHt-**StSqEdgSd-No1com**
Retaining pieces	Timbers	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**
Wheel guards	Timbers	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**
Rail posts	Posts	**1com**	**1com**	**1com**
Railing	Dimension	**1com**	**1com**	**1com**
Fire stops	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Stadia				
Posts	Posts	**StSqEdgSd-No1com**	StSqEdgSd-No1com	**StSqEdgSd-No1com**
Stringers	Stringers	DseHt-**StSqEdgSd-No1com**	DseHt-**StSqEdgSd-No1com**	DseHt-**StSqEdgSd-No1com**
Braces (diagonal)	Joists	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**	StSqEdgSd-**No1com**
Seats	Finish lumber	**B&Btr**	**B&Btr**	**B&Btr**
Back rests	Dimension	**1com**	**1com**	**1com**
Seat supports	Dimension	**1com**	**1com**	**1com**
Planking, ramps, decks	Dimension	**1com**	**1com**	**1com**
Railing	Dimension	**1com**	**1com**	**1com**
Rail posts	Dimension	**1com**	**1com**	**1com**
Walls, front, boxes, press box	Finish lumber (pattern)	**B&Btr-1com**	**B&Btr-1com**	**B&Btr-1com**

NOTE.—The grades in boldface type are suitable for use under ordinary conditions. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for use where the requirements are not exacting are shown to the right.

Association standard grades are shown except in cases where the association concerned does not publish structural grades. In such cases, the American Lumber Standards structural grades are used and are indicated by two asterisks (**).

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Dwelling construction	Sugar pine	California white pine	Idaho white pine	Pondosa pine	Northern white pine	Norway pine
	California White and Sugar Pine Manufacturers Association	California White and Sugar Pine Manfacturers Association	Western Pine Manufacturers Association	Western Pine Manufacturers Association	Northern Pine Manufacturers Association	Northern Pine Manufacturers Association
Interior uses:						
Finish and woodwork (natural finish)	**B&Btr**	**B&Btr**	**B&Btr**	**B&Btr**	**C&Btr**	**C&Btr**
Finish and woodwork (paint finish)	C-D-1com	C-D-1com	C-D	C-D-1com	**C**	**C**
Moldings (natural and paint finish)	**C&Btr**	**C&Btr**	**C&Btr**	**C&Btr**	**C&Btr**	**C&Btr**
Flooring:						
Living and dining room, hall, etc	.....	.....	.....	.....	.....	**D**
Bedroom	.....	.....	.....	.....	.....	**D**
Kitchen (not to be covered)	.....	.....	.....	.....	.....	**D**
Kitchen (to be covered)	.....	.....	.....	.....	.....	**D**
Shelving	1com-2com	**1com**-2com	**1com**-2com	1com-2com	D-**1com**-2com	D-**1com**-2com
Stepping	.....	**C&Btr**-1com	.....	**C&Btr**-1com	.....	**D**
Exterior uses:						
Window and door frames	C-D-1com	C-D-1com	C-D-1com	C-D-1com	C-D-1com	C-D
Bungalow and colonial siding	B&Btr-C-D	B&Btr-C-D	B&Btr-C-D	B&Btr-C-D	B&Btr-C-D	
Bevel siding	B&Btr-C-D	B&Btr-C-D	B&Btr-C-D	B&Btr-C-D	B&Btr-C	**C&Btr**
Rustic and drop siding	**C&Btr**-1com-2com	C&Btr-D-1com-2com	B&Btr-C-1com-2com	B&Btr-C-D-1com-2com	1com-2com	1com
Porch flooring (covered)	.....	C&Btr-D-1com	.....	C&Btr-D-1com	D-1com	D
Porch flooring (uncovered)	.....	.....	.....	.....	D-1com	D
Stepping	.....	.....	.....	.....	1com	D
Exterior trim	C-D-1com-2com	C-D-1com-2com	C-D-1com-2com	C-D-1com-2com	C-D-1com	**C-D**
Sheathing, etc.:						
Wall sheathing	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com
Roof sheathing	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	**3com**-4com	**3com**-4com
Subflooring	**2com-3com**-4com	**2com-3com**-4com	**2com-3com**-4com	**2com-3com**-4com	**3com**-4com	**3com**-4com
Framing:						
Posts	.....	.....	.....	.....	.....	**1com**
Girders	.....	**1com**	.....	.....	**1com**	**1com**
Sills	.....	**1com**	.....	.....	**1com**	**1com**
Joists and rafters	**1com**	**1com**	.....	.....	**1com**	**1com**
Plates, headers, braces	1com-**2com**	1com-**2com**	.....	.....	1com-**2com**	1com-**2com**
Studs	1com-**2com**	1com-**2com**	.....	.....	1com-**2com**	1com-**2com**
Cross-bridging, ribbons, ties	1com-**2com**	1com-**2com**	.....	.....	1com-**2com**	1com-**2com**

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Farm uses	Sugar pine	California white pine	Idaho white pine	Pondosa pine	Northern white pine	Norway pine
	California White and Sugar Pine Manufacturers Association	California White and Sugar Pine Manufacturers Association	Western Pine Manufacturers Association	Western Pine Manufacturers Association	Northern Pine Manufacturers Association	Northern Pine Manufacturers Association
Barns and other large buildings:						
Framing:						**1com**
Posts	.....	.....	.....	.....	**1com**	**1com**
Girders	.....	**1com**	.....	.....	**1com**-2com	**1com**-2com
Sills	.....	**1com**-2com	.....	.....		
Joists, rafters, trusses, plates and headers, braces, collar beams	**1com**-2com	**1com**-2com	.....	.....	**1com**-2com	**1com**-2com
Studs	**1com**-2com	**1com**-2com	.....	.....	**1com**-2com	**1com**-2com
Cross-bridging, ribbons	1com-**2com**	1com-**2com**	.....	.....	1com-**2com**	1com-**2com**
Drop siding, barn boards, and battens	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-2com
Exterior trim and doors	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing, roof and wall	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com
Heavy flooring	**1com**-2com	**1com**-2com	.....	.....	**1com**-2com	**1com**-2com
Subflooring	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	**3com**-4com	**3com**-4com
Grooved roofing	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Stanchions and stalls	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Mangers	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**	1com-**2com**
Small farm structures (separate and lean-to sheds, stock shelters, hog, poultry, and dairy houses, small granaries):						
Framing:						
Posts, girders, sills, joists, rafters	1com-**2com**	1com-**2com**	.....	.....	1com-**2com**	1com-**2com**
Studs, plates, headers, braces, collar ties, cross-bridging, ribbons	**2com**-3com	**2com**-3com	.....	.....	**2com**-3com	**2com**-3com
Siding, barn boards, exterior trim	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Flooring	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing (covered)	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com	2com-**3com**-4com
Inside equipment (roosts, nests, racks, shelving)	**2com**-3com	**2com**-3com	**2com**-3com	**2com**-3com	**2com**-3com	**2com**-3com
Corn cribbing	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	**2com**-3com	**1com**-2com
Gates and fencing	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com	**2com**-3com	**2com**-3com
General uses related to building construction						
Scaffolding	1com-2com	1com-2com	1com-2com	1com-2com	1com	1com
Staging	**1com**	**1com**	**1com**	**1com**	**1com**	**1com**
Concrete forms:						
Boards	**2com**-3com	**2com**-3com	**2com**-3com	**2com**-3com	**3com**-4com	**3com**-4com
Dimension	**1com**-2com	**1com**-2com	**1com**-2com	1com-2com	**1com**-2com	**1com**-2com

NOTE.—Grades used for standard permanent construction are in boldface type. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for more economical construction, where the requirements are not severe, or for temporary work are shown to the right.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Sugar pine California White and Sugar Pine Manufacturers Association	California white pine California White and Sugar Pine Manufacturers Association	Idaho white pine Western Pine Manufacturers Association
Bridge and construction timber:				
Combination and Howe truss spans:				
Compression members	Posts and timbers			
Tension	Joist and plank			
Diagonals subject to reverse stress	Posts and timbers			
Floor beams and stringers	Beams and stringers			
Ties	Timbers			
Guard timbers	Timbers			
Railing	Dimension	1com	1com	1com
Stiffeners	Dimension	1com	1com	1com
Splices	Dimension	1com	1com	1com
Nailing strips	Dimension	1com	1com	1com
Grillage	Timbers			
Deck plank	Dimension	1com	1com	1com
Bridging	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Piles and frame trestles:				
Sills and mud sills	Timbers			
Posts	Posts			
Caps	Timbers			
Sash bracing	Plank			
Cross bracing	Plank			
Longitudinal bracing	Plank			
Girts	Timbers			
End planks	Planks			
Stringers	Stringers			
Ties	Timbers			
Guard timbers	Timbers			
Planking for ballasted deck	Plank			
Railing	Dimension	1com	1com	1com
Falsework:				
Sills and mud sills	Timbers			
Posts	Posts			
Caps	Timbers			
Stringers	Stringers			
Truss timbers	Timbers			
Centering	Dimension	1com	1com	1com
Lagging	Dimension	1com	1com	1com
Bracing	Plank			
Wedges	Dimension	1com	1com	1com
Scaffolding	Dimension	1com-2com	1com-2com	1com-2com
Concrete forms:				
Dimension lumber	Dimension	1com-2com	1com-2com	1com-2com
D & M planks	.....	1com-2com	1com-2com	1com-2com
Bracing	Boards	1com-2com	1com-2com	1com-2com

Tanks and supports:				
Sills	Timbers			
Posts	Posts			
Caps	Timbers			
Bracing	Plank			
Joists	Joist			
D & M flooring	Heavy flooring	**C**	**C**	**C**
*Staves	.....	**Tank Stock**	**Tank Stock**	**Tank Stock**
Rafters	Dimension	**1com**-2com	1com-2com	**1com**-2com
Roof	Shiplap	**1com-2com**-3com	**1com-2com**-3com	**1com-2com-3com**
Ladders, etc	.....	C-1com	C-1com	C-1com
Frost box material	Shiplap	**1com**-2com	**1com**-2com	**1com**-2com
Docks and wharves:				
Timber sheet piling	Timbers			
Timber in cribs	Timbers			
Caps	Timbers			
Stringers	Stringers			
Bracing	Plank			
Guard timber	Timbers			
Ties	Timbers			
Plank decking	Plank			
Mooring posts	Timbers			
Fenders and wales	Timbers			
Coaling and ore stations:				
Sills and mud sills	Timbers			
Posts	Posts			
Caps	Timbers			
Bracing	Plank			
Stringers	Stringers			
Joists	Joists			
Bin lining	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Flooring	Boards	**1com-2com**-3com	**1com-2com**-3com	**1com-2com**-3com
Chutes	Boards	**1com-2com**-3com	**1com-2com**-3com	**1com-2com**-3com
Decking	Boards	**1com-2com**-3com	**1com-2com**-3com	**1com-2com**-3com
Coal pockets and bins	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roofing	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Tunnels:				
Posts	Posts			
Sills	Timbers			
Caps	Timbers			
Segments	Timbers			
Lagging	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Struts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Caisson	Timbers			

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

The American Lumber Standards structural grades used by the A.R.E.A. have been converted into the corresponding association grades in cases where associations publish such grades. Otherwise, the American Lumber Standards structural grades have been used.

Grades recommended by the A.R.E.A. are in boldface type. Alternate grades of better quality are shown to the left, and alternate grades of lower quality are shown to the right.

An asterisk (*) indicates that the particular grade recommended by the A.R.E.A. is not manufactured in the species concerned.

Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the associations publishing rules covering the various species are shown in the column headings.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Pondosa pine Western Pine Manufacturers Association	Northern white pine Northern Pine Manufacturers Association	Norway pine Northern Pine Manufacturers Association
Bridge and construction timber:				
Combination and Howe truss spans:				
Compression members	Posts and timbers			
Tension	Joist and plank			
Diagonals subject to reverse stress	Posts and timbers			
Floor beams and stringers	Beams and stringers			
Ties	Timbers			
Guard timbers	Timbers			
Railing	Dimension	1com	1com	1com
Stiffeners	Dimension	1com	1com	1com
Splices	Dimension	1com	1com	1com
Nailing strips	Dimension	1com	1com	1com
Grillage	Timbers			
Deck plank	Dimension	1com	1com	1com
Bridging	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Piles and frame trestles:				
Sills and mud sills	Timbers			
Posts	Posts			
Caps	Timbers			
Sash bracing	Plank			
Cross bracing	Plank			
Longitudinal bracing	Plank			
Girts	Timbers			
End planks	Planks			
Stringers	Stringers			
Ties	Timbers			
Guard timbers	Timbers			
Planking for ballasted deck	Plank			
Railing	Dimension	1com	1com	1com
Falsework:				
Sills and mud sills	Timbers			
Posts	Posts			
Caps	Timbers			
Stringers	Stringers			
Truss timbers	Timbers			
Centering	Dimension	1com	1com	1com
Lagging	Dimension	1com	1com	1com
Bracing	Plank			
Wedges	Dimension	1com	1com	1com
Scaffolding	Dimension	1com-2com	1com-2com	1com-2com
Concrete forms:				
Dimension lumber	Dimension	1com-2com	1com-2com	1com-2com
D & M planks		1com-2com	1com-2com	1com-2com
Bracing	Boards	1com-2com	1com-2com	1com-2com

Tanks and supports:				
Sills	Timbers			
Posts	Posts			
Caps	Timbers			
Bracing	Plank			
Joists	Joist			
D & M flooring	Heavy flooring	C	C	C
*Staves		Tank Stock	Tank Stock	Tank Stock
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Ladders, etc		C-1com	C-1com	C-1com
Frost box material	Shiplap	1com-2com	1com-2com	1com-2com
Docks and wharves:				
Timber sheet piling	Timbers			
Timber in cribs	Timbers			
Caps	Timbers			
Stringers	Stringers			
Bracing	Plank			
Guard timber	Timbers			
Ties	Timbers			
Plank decking	Plank			
Mooring posts	Timbers			
Fenders and wales	Timbers			
Coaling and ore stations:				
Sills and mud sills	Timbers			
Posts	Posts			
Caps	Timbers			
Bracing	Plank			
Stringers	Stringers			
Joists	Joists			
Bin lining	Dimension	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Flooring	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Chutes	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Decking	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Coal pockets and bins	Dimension	1com-2com	1com-2com	1com-2com
Roofing	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-2com
Tunnels:				
Posts	Posts			
Sills	Timbers			
Caps	Timbers			
Segments	Timbers			
Lagging	Dimension	1com-2com	1com-2com	1com-2com
Struts	Dimension	1com-2com	1com-2com	1com-2com
Caisson	Timbers			

NOTE.—The railroad uses shown (excluding rolling stock) were taken from the *Report* of Committee VII of the A.R.E.A. on "Wooden Bridges and Trestles," as contained in its *Bull.* 284, February, 1926.

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Two asterisks (**) indicate that the grades shown are American Lumber Standards structural grades. Although they are not manufactured regularly, they may be obtained upon request.

The names of the associations publishing rules covering the various species are shown in the column headings.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Sugar pine	California white pine	Idaho white pine
		California White and Sugar Pine Manufacturers Association	California White and Sugar Pine Manufacturers Association	Western Pine Manufacturers Association
Station buildings, passenger, freight, platform shelters:				
Caps	Timbers			
Sills	Timbers			
Posts	Timbers			
Stringers	Stringers			
Joists	Joists			
Bridging	Boards	2com-**3com**	2com-**3com**	2com-**3com**
Subflooring	Ship lap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com-3com**
Finish flooring (natural finish)	Flooring			
Finish flooring (paint finish)	Flooring			
Studding and plates	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Ship lap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Siding	Siding	B&Btr-C-D-1com	B&Btr-C-D-1com	B&Btr-C-D-1com
Ceiling (natural finish)	Ceiling	*C&Btr	*C&Btr	B&Btr
Ceiling (paint finish)	Ceiling	C&Btr-D	C&Btr-D	C-D
Truss timbers	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Purlins	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roof boards	Ship lap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Shingles (roof)	Shingles			
Shingles (side walls)	Shingles			

Station buildings, passenger, freight, platform shelters, continued:				
Door and window frames	Finish lumber	C-D-1com	C-D-1com	C-D-1com
Outside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D-1com
Inside finish (natural)	Finish lumber	B&Btr	B&Btr	B&Btr
Inside finish (paint)	Finish lumber	C-D-1com	C-D-1com	C-D-1com
Millwork (moldings)	Molding	C&Btr	C&Btr	C&Btr
Millwork (stairs)	Finish lumber	B&Btr-C-D	B&Btr-C-D	B&Btr-C-D
Partitions	Partition	C&Btr-D-1com	C&Btr-D-1com	B&Btr-C-D-1com
Shelving	Finish lumber	B&Btr-C-D	B&Btr-C-D	B&Btr-C-D
Engine houses and machine shops:				
Caps	Timbers			
Sills	Timbers			
Posts	Timbers			
Stringers	Stringers			
Joists	Joists			
Bridging	Boards	2com-3com	2com-3com	2com-3com
Flooring	Dimension			
Pit timbers	Timbers			
Studding	Dimension	1com-2com	1com-2com	1com-2com
Furring	Strips	1com-2com-3com	1com-2com-3com	1com-2com-3com
Siding	Siding	C&Btr-1com	C&Btr-D-1com	B&Btr-C-D-1com
Ceiling	Ceiling	C&Btr-D-1com	C&Btr-D-1com	B&Btr-C-D-1com
Truss lumber	Dimension	1com-2com	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof boards	Ship-lap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Shingles	Shingles			
Door and window frames	Finish lumber	C-D-1com	C-D-1com	C-D-1com
Outside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D1com
Inside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D-1com
Millwork	Finish lumber	C-D-1com	C-D-1com	C-D-1com
Sleepers	Dimension	1com-2com	1com-2com	1com-2com

RANGES OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Sugar pine	California white pine	Idaho white pine
		California White and Sugar Pine Manufacturers Association	California White and Sugar Pine Manufacturers Association	Western Pine Manufacturers Association
Section houses and small buildings:				
Posts	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Sills	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Caps	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Joists (section houses)	Dimension	**1C**	**1C**	**1C**
Joists (small buildings)	Joist			
Bridging	Boards	2com-**3com**	2com-**3com**	2com-**3com**
Sub-flooring	Ship-lap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Finish flooring (natural finish)	Flooring			
Finish flooring (paint finish)	Flooring			
Studding and plates	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Ship-lap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Siding	Siding	**C&Btr**-1com	**C&Btr**-D-1com	B&Btr-C-D-1com
Ceiling	Ceiling	**C&Btr**-D-1com	**C&Btr**-D-1com	B&Btr-C-D-1com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roofboards	Ship-lap	1com-**2com**-3com	1com-**2com**-3com	1com-2com-3com
Shingles	Shingles			
Door and window frames	Finish lumber	C-D-1com	C-D-1com	C-D-1com
Outside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D-1com
Inside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D-1com
Millwork	Finish lumber	C-D-1com	C-D-1com	C-D-1com
Warehouse and ice houses:				
Caps	Timbers			
Sills	Timbers			

Warehouse and ice houses, continued:				
Posts	Timbers			
Stringers	Stringers			
Joists (warehouses)	Joists			
Joists (ice houses)	Dimension	**1com**	**1com**	**1com**
Bridging	Boards	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Subflooring	Boards	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Finish flooring	Flooring			
Studding and plates	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Ship-lap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Siding	Siding	**C&Btr**-1com	**C&Btr-D**-1com	B&Btr-C-D-1com
Ceiling	Ceiling	**C&Btr-D**-1com	**C&Btr-D**-1com	B&Btr-**C-D**-1com
Truss timbers	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Purlins	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roof-boards	Ship-lap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Shingles	Shingles			
Door and window frames	Finish lumber	**C-D**-1com	**C-D**-1com	**C-D**-1com
Outside finish lumber	Finish lumber	**C-D**-1com	C-D-1com	C-D-1com
Inside finish lumber	Finish lumber	**C-D**-1com	C-D-1com	**C-D**-1com
Millwork	Finish lumber	**C-D**-1com	**C-D**-1com	C-D-1com
Sleepers	Strips	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Pondosa pine	Northern white pine	Norway pine
		Western pine Manufacturers Association	Northern Pine Manufacturers Association	Northern Pine Manufacturers Association
Station buildings, passenger, freight, platform shelters:				
Caps	Timbers			
Sills	Timbers			
Posts	Timbers			
Stringers	Stringers			
Joists	Joists			
Bridging	Boards	2com-**3com**	2com-**3com**	2com-**3com**
Sub-flooring	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Finish flooring (natural finish)	Flooring			
Finish flooring (paint finish)	Flooring	.....	.....	**D**
Studding and plates	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Siding	Siding	**B&Btr**-C-D-1com	**B&Btr**-C-1com	**C&Btr**-1com
Ceiling (natural finish)	Ceiling	**B&Btr**	**1com**	**1com**
Ceiling (paint finish)	Ceiling	C-D	**1com**	**1com**
Truss timbers	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Purlins	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Shingles (roof)	Shingles			
Shingles (side walls)	Shingles			
Door and window frames	Finish lumber	**C-D-1com**	**C&Btr**	**C-D**

Station buildings, passenger, freight, platform shelters, continued:				
Outside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D
Inside finish (natural)	Finish lumber	B&Btr	C&Btr	C&Btr
Inside finish (paint)	Finish lumber	C-D-1com	C-D-1com	C-D
Millwork (moldings)	Molding	C&Btr	C&Btr	C&Btr
Millwork (stairs)	Finish lumber	B&Btr-C-D	C&Btr	C&Btr
Partitions	Partition	B&Btr-C-D-1com	B&Btr-C-1com	C&Btr--1com
Shelving	Finish lumber	B&Btr-C-D	B&Btr-C-D	C&Btr-D
Engine houses and machine shops:				
Caps	Timbers			
Sills	Timbers			
Posts	Timbers			
Stringers	Stringers			
Joists	Joists			
Bridging	Boards	2com-3com	2com-3com	2com-3com
Flooring	Dimension	.....	.....	1com
Pit timbers	Timbers			
Studding	Dimension	1com-2com	1com-2com	1com-2com
Furring	Strips	1com-2com-3com	1com-2com-3com	1com-2com-3com
Siding	Siding	B&Btr-C-D-1com	B&Btr-C-1com	C&Btr-1com
Ceiling	Ceiling	B&Btr-C-D-1com	1com	1com
Truss lumber	Dimension	1com-2com	1com-2com	1com-2com
Purlins	Dimension	1com-2com	1com-2com	1com-2com
Rafters	Dimension	1com-2com	1com-2com	1com-2com
Roof boards	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Shingles	Shingles			
Door and window frames	Finish lumber	C-D-1com	C&Btr-1com	C-D
Outside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D
Inside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D
Millwork	Finish lumber	C-D-1com	C-D-1com	C-D
Sleepers	Dimension	1com-2com	1com-2com	1com-2com

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Pondosa pine	Northern white pine	Norway pine
		Western pine Manufacturers Association	Northern Pine Manufacturers Association	Northern Pine Manufacturers Association
Section houses and small buildings:				
Posts	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Sills	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Caps	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Joists (section houses)	Dimension	**1C**	**1C**	**1C**
Joists (small buildings)	Joist			
Bridging	Boards	2com-**3com**	2com-**3com**	2com-**3com**
Subflooring	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Finish flooring (natural finish)	Flooring			
Finish flooring (paint finish)	Flooring	.....	.....	**D**
Studding and plates	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Siding	Siding	B&Btr-C-D-1com	B&Btr-C-1com	C&Btr-1com
Ceiling	Ceiling	B&Btr-C-D-1com	**1com**	**1com**
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roofboards	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Shingles	Shingles			
Door and window frames	Finish lumber	C-D-1com	C&Btr-1com	C-D
Outside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D
Inside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D
Millwork	Finish lumber	C-D-1com	C-D-1com	C-D
Warehouses and ice houses:				
Caps	Timbers			
Sills	Timbers			
Posts	Timbers			

Warehouses and ice houses, continued:				
Stringers	Stringers			
Joists (warehouse)	Joists			
Joists (ice house)	Dimension	**1com**	**1com**	**1com**
Bridging	Boards	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Subflooring	Boards	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Finish flooring	Flooring	.....	.....	**D**
Studding and plates	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Furring	Strips	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Siding	Siding	B&Btr-C-D-1com	B&Btr-C-1com	**C&Btr**-1com
Ceiling	Ceiling	**B&Btr**-C-D-1com	**1com**	**1com**
Truss timbers	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Purlins	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roof boards	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Shingles	Shingles			
Door and window frames	Finish lumber	C-D-1com	**C&Btr**-1com	C-D
Outside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D
Inside finish lumber	Finish lumber	C-D-1com	C-D-1com	C-D
Millwork	Finish lumber	C-D-1com	C-D-1com	C-D
Sleepers	Strips	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com

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The names of the associations publishing rules covering the various species are shown in the column headings.

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Sugar pine	California white pine	Idaho white pine
		California White and Sugar Pine Manufacturers Association	California White and Sugar Pine Manufacturers Association	Western Pine Manufacturers Association
Miscellaneous roadway material				
Crossing plank	Dimension			
Platforms:				
Posts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Caps	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sills	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Stringers	Stringers			
Joists	Joists			
Bridging	Boards	2com-**3com**	2com-**3com**	2com-**2com**
Planking	Dimension			
Railing	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Steps	Boards			
Skids	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Stock guards:				
Posts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Ties	Timbers			
Wing fences and aprons	Boards	**1com**-2com	**1com**-2com	**1com**-2com
Slats	Boards	**1com**-2com	**1com**-2com	**1com**-2com
Fillers	Boards	1com-**2com**	1com-**2com**	1com-**2com**
Signs and posts:				
Posts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Bracing	Dimension	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Molding	Molding	C&Btr	C&Btr	C&Btr
Sign Boards	Finish lumber	B&Btr-C-1com	B&Btr-C-1com	B&Btr-C-1com
Fencing, including snow fence:				
Posts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Bracing	Boards	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Stringers	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Fence boards	Boards	1com-**2com**	1com-**2com**	1com-**2com**
Gate materials	Boards	**1com**-2com	**1com**-2com	**1com**-2com
Stakes	Boards	1com-**2com**	1com-**2com**	1com-**2com**
Culverts and drains:				
Sills	Timbers			
Bracing	Boards	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Timbers	Timbers			
Planking	Dimension	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Grillage	Timbers			
Stock pens:				
Posts	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sills	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Fencing	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Studding	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Sheathing	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com

Roof boards	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com-3com**
Shingles	Shingles			
Outside finish lumber	Finish lumber	B&Btr-C-D-1com	B&Btr-C-D-1com	B&Btr-C-D-1com
Poles	Timbers			
Conduits	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Bumping blocks	Timbers			
Railroad cars[1]				
Battens, door	Strips	**1com**-2com	**1com**-2com	**1com**-2com
Beams, needle	Timbers			
Belt rail	Boards			
Boards, card, legend, number	Finish lumber	B&Btr-C-1com	B&Btr-C-1com	B&Btr-C-1com
Braces	Joists			
Carlines	Dimension			
Decking or flooring	Heavy flooring or decking			
Open cars				
Box cars				
Stock cars				
Subflooring				
Door header	Dimension			
Door, grain	Boards	**1com**	**1com**	**1com**
Door, side	Siding			
Fascia	Finish lumber			
Framing, car	Joists			
Framing, box car side door	Joists			
Lining	Lining			
Refrigerator and box car without siding				
Refrigerator and box car with siding		**1com**	**1com**	**1com**
Plank, side and end	Plank			
Posts, corner	Joist			
Posts, door	Joist			
Roofing	Roofing			
Single board and outside double board				
Double board inside		**1com**	**1com**	**1com**
Running boards	Finish lumber	**B&Btr**	**B&Btr**	**B&Btr**
Ridge pole	Dimension			
Siding or sheathing	Siding			
Sills	Stringers			
Stakes	Dimension			

[1] First grade recommended is for new cars, second, for repairs.

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Railroad uses	Item	Pondosa pine	Northern white pine	Norway pine
		Western Pine Manufacturers Association	Northern Pine Manufacturers Association	Northern Pine Manufacturers Association
Miscellaneous roadway material				
Crossing plank	Dimension	.....	.....	1com-2com
Platforms:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Caps	Dimension	1com-2com	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com	1com-2com
Stringers	Stringers	.....	.....	
Joists	Joists	.....	.....	
Bridging	Boards	2com-3com	2com-3com	2com-3com
Planking	Dimension	.....	.....	1com-2com
Railing	Dimension	1com-2com	1com-2com	1com-2com
Steps	Boards	.....	.....	1com-2com
Skids	Dimension	1com-2com	1com-2com	1com-2com
Stock guards:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Ties	Timbers	.....	.....	
Wing fences and aprons	Boards	1com-2com	1com-2com	1com-2com
Slats	Boards	1com-2com	1com-2com	1com-2com
Fillers	Boards	1com-2com	1com-2com	1com-2com
Signs and posts:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Bracing	Dimension	1com-2com-3com	1com-2com-3com	1com-2com-3com
Molding	Molding	C&Btr	C&Btr	C&Btr
Sign boards	Finish lumber	B&Btr-C-1com	B&Btr-C-1com	C&Btr-1com
Fencing, including snow fence:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Bracing	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Stringers	Dimension	1com-2com	1com-2com	1com-2com
Fence boards	Boards	1com-2com	1com-2com	1com-2com
Gate materials	Boards	1com-2com	1com-2com	1com-2com
Stakes	Boards	1com-2com	1com-2com	1com-2com
Culverts and drains:				
Sills	Timbers	.....	.....	
Bracing	Boards	1com-2com-3com	1com-2com-3com	1com-2com-3com
Timbers	Timbers	.....	.....	
Planking	Dimension	1com-2com-3com	1com-2com-3com	1com-2com-3com
Grillage	Timbers	.....	.....	
Stock pens:				
Posts	Dimension	1com-2com	1com-2com	1com-2com
Sills	Dimension	1com-2com	1com-2com	1com-2com
Fencing	Dimension	1com-2com	1com-2com	1com-2com
Studding	Dimension	1com-2com	1com-2com	1com-2com
Sheathing	Shiplap	1com-2com-3com	1com-2com-3com	1com-2com-3com
Rafters	Dimension	1com-2com	1com-2com	1com-2com

Roof boards	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Shingles	Shingles			
Outside finish lumber	Finish lumber	B&Btr-C-D-1com	B&Btr-C-D-1com	C&Btr-D-1com
Poles	Timbers	.....	.....	
Conduits	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Bumping blocks	Timbers	.....	.....	
Railroad cars[1]				
Battens, door	Strips	**1com**-2com	**1com**-2com	**1com-2com**
Beams, needle	Timbers			
Belt rail	Boards			
Boards, card, legend, number	Finish lumber	B&Btr-C-1com	B&Btr-C-1com	C&Btr-1com
Braces	Joists			
Carlines	Dimension	.....	.....	**1com**
Decking or flooring	Heavy flooring or decking			
Open cars				
Box cars				
Stock cars				
Subflooring				
Door header	Dimension			
Door, grain	Boards	**1com**	**1com**	**1com**
Door, side	Siding	.....	.....	C&Btr-1com
Fascia	Finish lumber	.....	C&Btr	C&Btr
Framing, car	Joists	.....	.....	**1com**
Framing, box car side door	Joists	.....	.....	**1com**
Lining	Lining			
Refrigerator and box car without siding	.....	.....	.....	C&Btr
Refrigerator and box car with siding	.....	**1com**	**1com**	**1com**
Plank, side and end	Plank			
Posts, corner	Joist			
Posts, door	Joist			**1com**
Roofing	Roofing			**1com**
Single board and outside double board	.....	.....	.....	C&Btr-1com
Double board inside	.....	**1com**	**1com**	**1com**
Running boards	Finish lumber	**B&Btr**	**C&Btr**	**B&Btr**
Ridge pole	Dimension			
Siding or sheathing	Siding	.....	**1com**	C&Btr-1com
Sills	Stringers	.....	.....	**1com**
Stakes	Dimension	.....	.....	**1com**

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RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Industrial buildings	Item	Sugar pine	California white pine	Idaho white pine
		California White and Sugar Pine Manufacturers Association	California White and Sugar Pine Manufacturers Association	Western Pine Manufacturers Association
Posts	Timbers			
Caps	Timbers			
Girders	Beams			
Stringers	Stringers			
Heavy joists	Joists			
Heavy flooring	Heavy flooring			
Plates	Joists			
Truss members	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roof planking	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Bridging	Boards	2com-**3com**	2com-**3com**	2com-**3com**
Sills	Timbers			
Airplane hangars				
Framing:				
Sills	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Studs	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Plates	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Truss members	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Siding	Siding	**C&Btr**-1com	**C&Btr**-D-1com	B&Btr-C-1com
Sheathing, wall and roof	Ship lap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Trim, exterior and interior, window and door frames	Finish lumber	**C-D**-1com	**C-D**-1com	**C-D**-1com
Highway uses				
Bridges:				
Posts or columns	Posts			
Mud-sills	Timbers			
Sills	Timbers			
Caps	Timbers			
Bracing	Joists			
Truss members	Joists			
Stringers	Stringers			
Floor beams	Stringers			
Bridging	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Nailing strips	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Flooring	Plank			
Retaining pieces	Timbers			
Wheel guards	Timbers			
Rail posts	Posts			
Railing	Dimension			
Fire stops	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Stadia				
Posts	Posts			
Stringers	Stringers			
Braces (diagonal)	Joists			
Seats	Finish lumber			
Back rests	Dimension			
Seat supports	Dimension			
Planking, ramps, decks	Dimension			
Railing	Dimension			
Rail posts	Dimension			
Walls, front, boxes, press box	Finish lumber (pattern)	**C&Btr**-1com	**C&Btr**-D-1com	B&Btr-C-1com

NOTE.—The grades in boldface type are suitable for the use under ordinary conditions. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for use where the requirements are not exacting are shown to the right.

Association standard grades are shown except in cases where the association concerned does not publish structural grades. In such cases, the American Lumber Standards structural grades are used and are indicated by two asterisks (**).

RANGE OF GRADES OF SOFTWOOD LUMBER USED FOR SPECIFIC PURPOSES (*Continued*)

Industrial buildings	Item	Pondosa pine	Northern white pine	Norway pine
		Western Pine Manufacturers Association	Northern Pine Manufacturers Association	Northern Pine Manufacturers Association
Posts	Timbers			
Caps	Timbers			
Girders	Beams			
Stringers	Stringers			
Heavy joists	Joists			
Heavy flooring	Heavy flooring	.....	.....	**1com**
Plates	Joists			
Truss members	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Roof planking	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Bridging	Boards	2com-**3com**	2com-**3com**	2com-**3com**
Sills	Timbers			
Airplane hangars				
Framing:				
Sills	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Studs	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Plates	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Rafters	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Truss members	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Siding	Siding	B&Btr-**C-D**-1com	C-1com	C&Btr-1com
Sheathing, wall and roof	Shiplap	1com-**2com**-3com	1com-**2com**-3com	1com-**2com**-3com
Trim, exterior and interior, window and door frames	Finish lumber	**C-D**-1com	**C-D**-1com	**C-D**
Highway uses				
Bridges:				
Posts or columns	Posts			
Mud sills	Timbers			
Sills	Timbers			
Caps	Timbers			
Bracing	Joists			
Truss members	Joists			
Stringers	Stringers			
Floor beams	Stringers			
Bridging	Dimension	**1com**-2com	**1com**-2com	**1com**-2com
Nailing strips	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Flooring	Plank			
Retaining pieces	Timbers			
Wheel guards	Timbers			
Rail posts	Posts	.....	.....	**1com**
Railing	Dimension	.....	.....	**1com**
Fire stops	Dimension	1com-**2com**	1com-**2com**	1com-**2com**
Stadia				
Posts	Posts			
Stringers	Stringers			
Braces (diagonal)	Joists			
Seats	Finish lumber			
Back rests	Dimension	.....	.....	**1com**
Seat supports	Dimension	.....	.....	**1com**
Planking, ramps, decks	Dimension	.....	.....	**1com**
Railing	Dimension	.....	.....	**1com**
Rail posts	Dimension	.....	.....	**1com**
Walls, front, boxes, press box	Finish lumber (pattern)	B&Btr-**C-D**-1com	C-**D**-1com	C&Btr-1com

NOTE.—The grades in boldface type are suitable for the use under ordinary conditions. Alternate grades for unusually high quality of construction are shown to the left, and alternate grades for use where the requirements are not exacting are shown to the right.

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